Green Energy and Technology

Mayken Espinoza-Andaluz ·
Martin Andersson · Tingshuai Li ·
Jordy Santana Villamar ·
Ángel Encalada Dávila ·
Ester Melo Vargas *Editors*

Congress on Research, Development and Innovation in Renewable Energies

Selected Papers from CIDiER 2021

Springer

Green Energy and Technology

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Editors
Mayken Espinoza-Andaluz
Faculty of Mechanical Engineering and Production Science
Escuela Superior Politecnica del Litoral
Guayaquil, Ecuador

Martin Andersson
Energy Sciences
Lund University
Lund, Sweden

Tingshuai Li
School of Materials and Energy
University of Electronic Science and Science and Technology of China
Chengdu, Sichuan, China

Jordy Santana Villamar
Faculty of Mechanical Engineering and Production Science
Escuela Superior Politecnica del Litoral
Guayaquil, Ecuador

Ángel Encalada Dávila
Faculty of Mechanical Engineering and Production Science
Escuela Superior Politecnica del Litoral
Guayaquil, Ecuador

Ester Melo Vargas
Faculty of Social and Humanistic Science
Escuela Superior Politecnica del Litoral
Guayaquil, Ecuador

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Preface

Figuring out solutions to face global warming is one of the key topics around the globe that has demanded great attention in the last decades. The acceleration of global warming, promoted mainly by the use of fossil fuels, produces hazardous effects and consequences on human well-being as well as economic and technological development of nations. These effects are evidenced in drastic changes to the environment such as glacial melting and natural disasters, which, in turn, put ecosystems in danger. On the other hand, the large emissions of polluting gases produced by fossil fuels, which are not renewable, make this resource not sustainable over time.

Due to this, international alliances, for instance, the European Green Deal, have arisen to face the challenges toward changing to a sustainable, clean, and economically viable energy matrix. In addition, one of the main concerns of the General Assembly of the United Nations regarding the 2030 Agenda is to promote sustainable initiatives related to developing renewable energies, such as SDG 7: Affordable and Clean Energy and SDG 13: Climate Action. On the other hand, Latin America also has a great interest in developing technologies that position renewable energies as the primary energy resource. However, strong cooperation synergies between countries that involve government, industry, and academia are missing to reach the common goals. Based on this, Congress on Research, Development, and Innovation in Renewable Energies (CIDiER 2021, acronyms from Spanish) had the objective put together teachers, students, researchers, engineers, and scientists from different disciplines and countries, mainly from Latin America, to present their latest studies and results.

This book consists of five key sections focused on solar, biomass, hydrogen, wind, and general renewable energy topics. Articles correspond to selected manuscripts from the Congress on Research, Development, and Innovation in Renewable Energies (CIDiER) 2021, held in Guayaquil, Ecuador (virtual mode), on September 20 and 21, 2021. This conference aimed to spread theoretical and experimental studies results and applications related to relevant topics in renewable energies and generate a space of multidisciplinary interaction to strengthen and establish new contact networks in the academic and research community. Participants from all disciplines related to renewable energy and several Latin-American countries contributed to this important event.

This edited book meets some major topics related to renewable energies, such as developing and studying new materials, process design and simulation, computational modeling, energy efficiency, and chemical and mechanical analysis, among others. Finally, the editors of this book would like to thank the Springer editorial team and all contributing authors for their commitment and collaborative effort that have realized this book.

Guayaquil, Ecuador
Lund, Sweden
Chendgu, China

Mayken Espinoza-Andaluz
Martin Andersson
Tingshuai Li
Jordy Santana Villamar
Ángel Encalada Dávila
Ester Melo Vargas

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About the Editors

Martin Andersson PhD, is an associate professor at Lund University. He earned his doctoral degree from the Division of Heat Transfer, Department of Energy Sciences, Lund University. Dr. Andersson was awarded the title of Docent in 2014, and in 2015 he was granted a Marie Curie Fellowship, one of Europe's most competitive and prestigious awards to foster interdisciplinary research and international collaborations. His primary areas of research include analysis of heat and mass transfer and other transport phenomena in solid oxide fuel cells (SOFC) and polymer electrolyte fuel cells (PEFC). His current research interests are focused on a comprehensive understanding of chemical reactions and nano-/micro-structured porous material effects on various transport processes in various components of fuel cell systems. He has been a reviewer for a number of international journals, including the *International Journal of Hydrogen Energy*, *International Journal of Energy Research*, *Energy and Fuels*, *Journal of Power Sources*, and *Journal of Porous Media*.

Ángel Encalada Dávila received his bachelor's degree in mechatronics engineering in 2021 from Escuela Superior Politécnica del Litoral (ESPOL). He is currently working as a data scientist in an international data analytics company. He has also a solid experience in software industry for ATMs. Furthermore, he collaborates as a data scientist at the Control, Modeling, Identification, and Applications Research Group (CoDAlab) at the Universitat Politècnica de Catalunya (UPC), Barcelona, Spain. His research interests include structural health monitoring (SHM) and fault prognosis applied to wind turbines and computer modeling applied to fuel cells. In addition, Mr. Encalada is author and co-author of several scientific articles that have been published in the journals like *Sensors*, *Energies*, and *Processes*. He recently worked as an organizer of the Congress of Research, Development, and Innovation in Renewable Energies (CIDiER), Guayaquil, Ecuador.

Mayken Espinoza-Andaluz PhD, is a full professor at Escuela Superior Politécnica del Litoral (ESPOL) and co-supervisor of PhD students in heat transfer and energy systems at Lund University. He earned his PhD in heat transfer from the Department of Energy Sciences at Lund University. His areas of research include renewable energy, fuel cells, proton-exchange membrane fuel cells (PEMFC), solid oxide fuel cells (SOFC), physical and chemical phenomena, energy efficiency, Lattice Boltzmann methods (LBM), and computational modeling. He is a reviewer for a number of international journals, including the *International Journal of Energy Research*, *International Journal of Hydrogen Energy*, and *Computers and Mathematics with Applications*.

Tingshuai Li PhD, is a professor at the University of Electronic Science and Technology of China (UESTC). He earned his PhD degree in materials chemistry and physics from Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences. Dr. Li carried out postdoctoral research at Nanyang Technological University and the University of South Carolina. He has published numerous scientific papers, applied for more than 10 patents, participated in the writing of 2 monographs, and presided over the Natural Science Foundation of China and key research and development projects in Sichuan Province. His primary areas of research include materials design for fuel cells and electrochemical synthesis of various fuels. He has been a reviewer for the *International Journal of Hydrogen Energy*, *Journal of Materials Chemistry A*, and *ACS Applied Materials & Interfaces*.

Ester Melo Vargas received her bachelor's degree in audit and management control in 2021 from the Escuela Superior Politécnica del Litoral (ESPOL), obtaining an honors diploma and an award for her thesis project related to the management of medical supplies in Ecuador during the Covid-19 pandemic. From 2019 to the present, she has served as a research assistant at the same institution. Her interest in research, technology, and gender inclusion in STEM have motivated her to participate in different technological innovation competitions, as well as in STEM projects sponsored by the US Embassy in Ecuador. This experience gave her the opportunity to do an internship in project engineering at Huawei Technologies (Guayaquil, Ecuador) in 2020. Her research interests include data analysis and fault detection applied to fuel cells and quality analysis and lean manufacturing applied to productivity management. In addition, Ms. Melo is the author and co-author of scientific articles that have been presented at congresses, conferences, and scientific dissemination meetings.

Jordy Santana Villamar received his bachelor's degree in mechanical engineering from Escuela Superior Politécnica del Litoral (ESPOL) in 2020, obtaining a diploma of distinction in research. He was a teaching assistant at the early stage of his undergraduate studies on subjects such as calculus, electromagnetics physics, and statistics. Then, he got a position as research assistant during his last four semester. Currently, he is a junior researcher at the Center of Renewable and Alternative Energy at ESPOL. His area of research is electrochemical tests to evaluate the performance in fuel cells and redox flow batteries applying EIS technique, sweep current, and linear and circular sweep voltammetry; expanded graphite-resin composite materials development with secondary fillers for bipolar plates; and modeling on transport phenomena. In addition, he has published several scientific papers in leading journals including the *International Journal of Hydrogen Energy*, *Journal of Electrochemical Society*, and *Energies*. He has also participated in congresses, international conferences, and meetings to spread his research work. He recently worked as an organizer of the Congress of Research, Development, and Innovation in Renewable Energies (CIDiER), Guayaquil, Ecuador.

Part I
Solar Energy

Proposal of a Colombian Refrigeration Potential Map Based on Solar Powered Absorption Cooling Systems

Jhojan Stiven Zea Fernández, Mario Luna-delRisco, Valeria Berrocal, Nildia Yamileth Mejias Brizuela, Carlos Arrieta González, Laura Paniagua, Sebastian Villegas Moncada, and Carlos A. Arredondo Orozco

1 Introduction

The growing concern about the effects of global warming, as well as the uncertainty due to finite reserves of fossil fuels, have turned the world's attention to nonconventional renewable energy sources as the way to a clean and environmentally friendly energy transition [2]. Colombia has pledged to take part in this transition through international agreements such as the Paris agreement [3]; however, the country is still lagging in the development of renewable energy sources in the national territory.

By 2021, less than 1% of the electricity generated in the country comes from nonrenewable energy sources such as biomass, solar, and wind energy, a very low percentage compared to more developed countries such as the United States, where 12% of the energy consumed comes from these sources [4]. According to the accelerated growth of renewable energy for the next decade, Colombia has set itself the goal of reaching 15% share of renewables by 2030, with emphasis on the north coast of the country [5], where there is great potential for solar and wind energy [6].

In view of the accelerated growth expected for renewable energy in the next decade, emphasis must be placed on how these new technologies can help

J. S. Zea Fernández · M. Luna-delRisco (✉) · V. Berrocal · C. Arrieta González
S. Villegas Moncada · C. A. Arredondo Orozco
Universidad de Medellín, Medellín, Colombia
e-mail: mluna@udemedellin.edu.co

N. Y. Mejias Brizuela
Universidad Politécnica de Sinaloa, Mazatlán, México

L. Paniagua
Benemerita Universidad Autónoma de Puebla, Puebla, México

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low-income people with no access to electrical energy. In Colombia, approximately 52% of the national territory is not connected to the electrical grid; this means that almost 2 million people who live in these places get sporadic and low-quality access to electricity or no access at all [1]. Since a large part of the people who live in non-interconnected areas engage in productive activities such as livestock, fishing, and agriculture, it is to be expected that part of the production is lost because they cannot cool their products.

The implementation of absorption cooling cycles that can use solar energy as a heat source means that large cooling centers could be available to residents of non-interconnected areas as a way of storing their products for later sale [7], thereby increasing the economic development and life quality [8]. However, not all areas of the country are suitable for the installation of these systems, since there are a wide variety of climates and weather conditions [9].

The objective of this chapter is to present a map of the absorption cooling potential for the Colombian territory. Maximum cooling volume capacity was determined based on data of solar radiation and temperature (mean values). Those variables were also used for the calculation of the system´s efficiency allowing the geolocation of non-interconnected areas where the industrial facilities might be placed.

2 System Description

The system consists of a condenser, an evaporator, an absorber, a generator, a pump, expansion valves, a heat exchanger, and a solar collector, as shown in Fig. 1.

The cycle is possible because of the ability of certain substances to perform absorption and desorption reactions. In this case, water absorbs ammonia vapor in the absorber and creates a solution with a weak water concentration; the solution has its pressure increased by means of a pump and is sent to the generator, in which the heat coming from the solar collector heats the solution and causes most of the ammonia vapor to be desorbed.

The high-pressure ammonia vapor shifts to liquid phase in the condenser and is expanded to a low pressure with an expansion valve; the low-pressure liquid is then converted into ammonia vapor in the evaporator and is sent to the absorber to restart the cycle. The solution that is left on the generator, now with a strong water concentration, exchanges heat with the refrigerant flow exiting the pump to increase the system's efficiency and is expanded, using an expansion valve to go once again into the absorber [10].

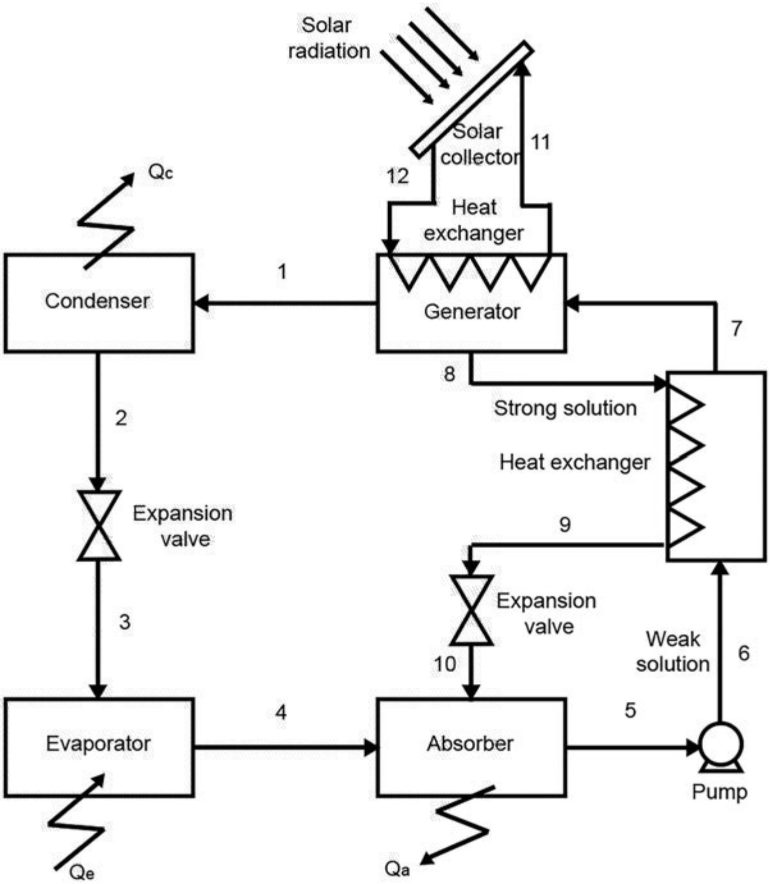

Fig. 1 System schematic

3 Modeling and Methodology

3.1 Symbols and Subscripts

Symbols

COP = Coefficient of performance
E = Efficiency
f = Mass flow ratio
h = Enthalpy [kJ/kg]
P = Pressure [kPa]
$\dot{m}$ = Mass flow [kg/s]

q = Heat per unit mass [kJ/kg]
Q = Heat [kJ]
$\dot{Q}$ = Heat rate [kW]
T = Temperature [°C]
⍰ = Power [kW]
x = Concentration [kg/kg]
G_{stc}
= Global irradiance on standard test conditions [1000 W/m^2]

Subscripts

a = Absorber
b = Pump
c = Condenser
e = Evaporator
l = Liquid
g = Generator
sc = Solar collector
ref = Refrigerant
sf = Strong solution
sd = Weak solution
v = Vapor

3.2 *Thermodynamic Model*

A simple steady-state model was considered for this particular study. There was no need for a thermal energy storage system. The model assumes heat and pressure losses on all the piping and units to be negligible and the refrigerant to be 100% ammonia (NH_3) [11]. The mass balances are presented in Eqs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 [11]:

$$\dot{m}_1 = \dot{m}_2 \tag{1}$$

$$\dot{m}_2 = \dot{m}_3 = \dot{m}_{ref} \tag{2}$$

$$\dot{m}_3 = \dot{m}_4 = \dot{m}_{ref} \tag{3}$$

$$\dot{m}_4 + \dot{m}_{10} = \dot{m}_5 \tag{4}$$

$$\dot{m}_9 = \dot{m}_{10} \tag{5}$$

$$\dot{m}_5 = \dot{m}_6 \tag{6}$$

$$\dot{m}_7 = \dot{m}_1 + \dot{m}_8 \tag{7}$$

$$\dot{m}_8 + \dot{m}_6 = \dot{m}_7 + \dot{m}_9 \tag{8}$$

$$\dot{m}_4 + \dot{m}_{10} = \dot{m}_5 \tag{9}$$

$$\dot{m}_9 = \dot{m}_8 \tag{10}$$

$$\dot{m}_{11} = \dot{m}_{12} \tag{11}$$

The generator is possible to perform an NH_3 balance, as seen in Eq. 12 [11]:

$$\dot{m}_7 x_7 = \dot{m}_1 x_1 + \dot{m}_8 x_8 \tag{12}$$

Equations 13 and 14, which are expressions for the strong solution mass flow rates, can be obtained from Eqs. 12 and 7 [11]:

$$\dot{m}_8 = \frac{x_7 - x_1}{x_8 - x_7} \dot{m}_1 \tag{13}$$

$$\dot{m}_7 = \frac{x_8 - x_1}{x_8 - x_7} \dot{m}_1 \tag{14}$$

From Eq. 13, the circulation ratio can be formulated as [11]:

$$f = \frac{\dot{m}_7}{\dot{m}_1} = \frac{x_8 - x_1}{x_8 - x_7} \tag{15}$$

The energy balances are performed as follows in Eqs. 16, 17, 18, 19, 20, 21, 22, 23, 24 and 25 [11]:

$$\dot{Q}_c = \dot{m}_{ref}(h_1 - h_2) \tag{16}$$

$$h_2 = h_3 \tag{17}$$

$$\dot{Q}_e = \dot{m}_{ref}(h_4 - h_3) \tag{18}$$

$$\dot{Q}_a = \dot{m}_4 h_4 + \dot{m}_{10} h_{10} - \dot{m}_5 h_5 \tag{19}$$

$$\dot{W}_b = \dot{m}_5(h_6 - h_5) \tag{20}$$

$$h_7 = h_6 + \frac{\dot{m}_8}{\dot{m}_6}(h_8 - h_9) \tag{21}$$

$$h_9 = h_{10} \tag{22}$$

$$\dot{m}_{12}(h_{12} - h_{11}) = \dot{m}_1 h_1 + \dot{m}_8 h_8 - \dot{m}_7 h_7 \tag{23}$$

$$\dot{m}_{12}(h_{12} - h_{11}) = G_{stc} A_{sc} E_{sc} \tag{24}$$

$$COP = \left[\frac{\dot{Q}_e}{G_{stc} A_{sc} E_{sc} + \dot{W}_b}\right] \tag{25}$$

The authors express Eq. 18 in terms of the circulation ratio when dividing the whole expression by $\dot{m}_4$ as presented in Eq. 26 [11]:

$$q_a = (h_5 - h_{10}) + f(h_{10} - h_5) \tag{26}$$

3.3 Methodology

The previous equations present an ideal absorption cooling system with no thermal energy storage system, assuming reference conditions for variables such as pressures and temperatures [12]. The model calculates the heat extracted by the heat pump ($\dot{Q}_e$) based on the solar irradiance and ambient temperature of a particular location.

A MATLAB script identifies the color of each pixel on the average ambient temperature and average peak sun hours (PSH) maps that the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) provides [13] [14] and translates it into usable data. The script then calculates the amount of daily cooling each pixel of the map can generate and the efficiency of the system (expressed by the COP on each pixel).

The thermodynamic properties for the NH_3-H_2O mixture are calculated with the equations proposed by Sun [15]. Then, in each pixel, the system is simulated by setting Tc to the mean ambient temperature of each pixel. In this simulation, the solar collector receives a constant solar irradiance of 1000 W/m^2. The cycle works for the equivalent time to PSH of the pixel by calculating the daily amount of cooling and the system efficiency depending on the ambient temperature.

The result is a map of the country in which each pixel has a value for maximum amount of cooling produced with 1 m^2 of solar collector and the system's efficiency, detailing the potential for the solar absorption system in every location of the region. The reference conditions considered were as follows:

T_g = 80 °C
T_a = 25 °C
T_e = -5 °C
$\dot{m}$ = 1 kg/s
E_{sc} = 90%
A_{sc} = 1 m^2

4 Results

The generated maps for daily cooling potential and system efficiency are presented in Figs. 2 and 3.