INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2017) 1–10

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

A renewable source based hydrogen energy system for residential applications

F. Sorgulu [a,b,*], I. Dincer [a,c]

[a] Faculty of Mechanical Engineering, Yildiz Technical University, Besiktas, Istanbul, Turkey
[b] Faculty of Technology, Kahramanmaras Sutcu Imam University, Elbistan, Kahramanmaras, Turkey
[c] Faculty of Engineering and Applied Science, University of Ontario Institute of Technology, Oshawa, Ontario, Canada

ARTICLE INFO

Article history:
Received 22 August 2017
Received in revised form
25 September 2017
Accepted 16 October 2017
Available online xxx

Keywords:
Efficiency
Electrolyser
Fuel cell
Hydrogen energy
Solar energy
Wind energy

ABSTRACT

In this study, both concentrated solar power and wind energy systems are integrated with electrolyser, fuel cell and absorption cooling subsystems to supply power, cooling, heating and hydrogen to residential applications in an environmentally benign and efficient manner. These subsystems are integrated in a unique way to manage the excess power through water electrolysis to produce and store hydrogen. Integrated systems are thermodynamically analyzed, and their performance is assessed comparatively. Solar radiation intensity, inlet temperature and wind velocity are taken into account, and hence their effects on the system performance are investigated. The results of this study show that the present system appears to be efficient, environmentally friendly and hence sustainable.

Introduction

Global energy demand has been increasing rapidly due to the technological and economic developments. As shown in Fig. 1, for example, the electricity consumption in developed countries is much above the world average [1]. Among the various affecting parameters, rapid population growth and urbanization have a major influence on energy demand and consumption. In USA, Canada and Australia, electricity consumption per capita has increased more than 5 MWh since 1970s [1]. In Canada, electricity is mainly generated by hydroelectric sources with almost 60%. Despite decreasing in last 40 years, Canada is the second biggest electricity producer of hydropower [2]. As shown in Fig. 2 electricity production is mainly supplied by hydropower and nuclear energy in Ontario, Canada [3]. However, almost all around the world electricity demand is mainly supplied by fossil fuels on a large scale so it has brought a lot of serious undeniable impact on the environment.

Based on the World Bank data, in the last 50 years, CO_2 emissions (metric tons per capita) have increased from 3.09 to 4.99 in the world. Countries such as Qatar, Kuwait, United Arab Emirates and Saudi Arabia, which provide electricity mainly by oil and fossil fuels due to their abundance, have the most value of CO_2 emissions per capita. As a result of the

* *Corresponding author*. Faculty of Mechanical Engineering, Yildiz Technical University, Besiktas, Istanbul, Turkey.
E-mail address: fatihs@yildiz.edu.tr (F. Sorgulu).

https://doi.org/10.1016/j.ijhydene.2017.10.101
0360-3199/

Nomenclature

A	Electrolyser cell area (cm^2)
ex	Total specific exergy (kJ/kg)
$\dot{E}x$	Exergy transfer rate (kW)
$\dot{E}x_D$	Exergy destruction rate (kW)
$\dot{E}x^Q$	Thermal exergy rate (kW)
FC	Fuel Cell
h	Enthalpy (kJ/kg)
LHV	Low Heating Value
$\dot{m}$	Mass flow rate (kg/s)
ORC	Organic Rankine Cycle
PEM	Polymer Electrolyte Membrane
PV	Photovoltaic
$\dot{Q}$	Heat transfer rate (kW)
s	Specific entropy (kJ/kgK)
$\dot{S}_{gen}$	Entropy generation rate (kW/K)
T	Temperature (K)
$\dot{W}$	Power production rate (kW)

Greek letters

η	Efficiency

Subscripts and superscripts

0	Initial
av	Average
b	Boundary
EL	Electrolyser
en	Energy
ex	Exergy
gen	Generated
in	Inlet
out	Outlet
ov	Overall
r	Reversible
s	Source
ST	Steam Turbine
WT	Wind Turbine

climate situation in the Gulf region, more than 60% of the produced power is used for cooling purposes while the increased need in this section requires more and more fossil fuel power plants to be installed [4]. Developed countries such as United States, Australia, Canada and Russian Federation follow these countries with a high value of CO_2 emissions per capita [5].

Renewable energy resources are recognized as potential solutions to overcome the drawbacks of fossil fuels. The issue was discussed in various critical international platforms, including the past Climate Change Conference in Paris, France. In this regard, hydrogen energy, as a carbon-free and sustainable energy carrier, is recognized a promising solution for energy demand. Combining renewable energy sources with the hydrogen energy systems is proposed as a unique integrated solution for global warming and energy related issues.

In conjunction with this, renewable energy based hydrogen energy is one of the most promising solutions to the environmental issues as a carbon free fuel. It is possible to eliminate or reduce the environmental pollution initiated by fossil fuels, particularly by reducing greenhouse gas emissions [6,7]. Solar energy can be considered as a promising solution to reach zero-emission process [8]. Besides, electricity cannot be stored and batteries or fuel cell systems require to meet the sustainability needs. Hydrogen and fuel cells are recognized for their higher efficiencies. Hydrogen is a carbon free energy carrier with high density [9,10]. Generated and stored hydrogen either goes directly to a fuel cell to produce electricity or through a compressor to run the fuel cell at high pressure.

Ozlu et al. [11] assessed and compared the electricity, heating and cooling demands in Southern regions of Ontario Province in Canada. They analyzed different systems such as ground and air source heat pump, photovoltaic panel, wind turbine and fuel cell systems. Furthermore, they analyzed both photovoltaics and wind turbines integrated with the fuel cell system. A thermodynamics, economic and environmental evaluation was studied by employing average weather conditions, electricity prices and average electricity loads in

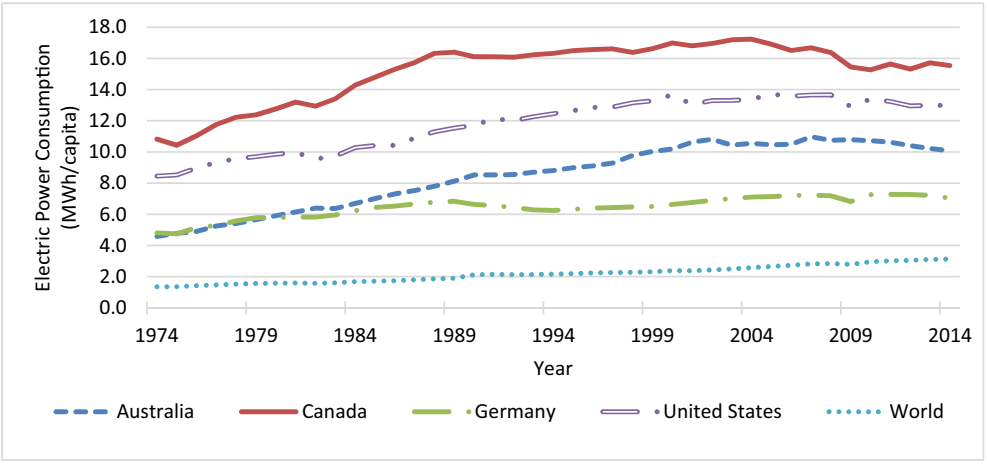

Fig. 1 – Electric power consumptions (MWh per capita) (data from Ref. [1]).

Please cite this article in press as: Sorgulu F, Dincer I, A renewable source based hydrogen energy system for residential applications, International Journal of Hydrogen Energy (2017), https://doi.org/10.1016/j.ijhydene.2017.10.101