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A technical, economic and environmental analysis of combining geothermal energy with carbon sequestration for hydrogen production

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Abstract

Among numerous techniques for the hydrogen production without harmful emissions, especially avoiding the carbon dioxide emissions, hydrogen technologies driven by geothermal energy represent an attractive solution. This paper is interested in the process by which the electricity generated from geothermal power plant that is operated using CO_2 as heat transmission fluid is exploited for hydrogen production through water electrolysis. A numerical simulation is used to evaluate the potential for hydrogen production and to estimate the levelized cost of electrolytic hydrogen. We also present a brief analysis of environmental issues, including the carbon tax. The results show that the process has a good potential for geothermal hydrogen production, is capable of producing about 22 kg/h of electrolytic hydrogen for the geothermal source of carbon dioxide mass flow rate of 40 kg/s and a temperature of 296 K. In economic regard, the electric energy system costs are the major component of the total hydrogen production cost (more than 90%). The estimated cost of hydrogen is 8.24 \$/kg H_2. By including the carbon tax, the cost of hydrogen production becomes far more competitive.

Keywords: Geothermal energy; CO_2 sequestration; alkaline electrolysis; hydrogen production; techno-economic modeling; environmental impact; numerical simulation.

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1. Introduction

The worldwide demand for energy has been increasing rapidly and almost exponentially since the industrial revolution, according to the International Energy Agency, global total primary energy supply more than doubled between 1971 and 2011, mainly relying on the utilization of unsustainable energy sources [1]. The depletion of some primary energy (oil and gas), with an associated acceleration of global warming, as a result of drastically increased greenhouse gas (GHG) emissions, where the carbon dioxide (CO_2) is the most important anthropogenic GHG, are all factors that have promoted a new environmental policy and accordingly a new energy policy. The environmental policy is based on reducing emissions, as required by the Kyoto Protocol signed on 11 December 1997 and ratified by hundred ninety-one countries in 2010 [2]. However, technologies that help reduce CO_2 emissions from fossil fuels can be a key Carbon abatement option responds to the Kyoto Protocol objective. CO_2 capture and storage (CCS) is particularly promising. CCS takes CO_2 from large stationary sources and stores it in deep geological layers to prevent its release into the atmosphere [3]. The sequestration of carbon is applied in the electricity generation. Previous literature, have considered the technical feasibility of carbon dioxide sequestration in deep saline aquifers, depleted hydrocarbon fields and exhausted oil and natural gas fields [4-9]. The economic benefits of process have been studied [10, 11]. The energy policy is based on renewable energy. A transition to a renewable based energy system is crucial. These energies are clean and inexhaustible. However, obstacles with renewable electric energy conversion systems are often referred to the intermittency of the energy sources; the need for their conversion into a versatile energy carrier in its use, storable, transportable and environmentally acceptable is required. Of all the candidates answering these criteria, hydrogen presents the best assets; it is the most abundant element in the universe; it is not pollutant [12]. Hydrogen produced from renewable energy sources offers the promise of a clean and sustainable energy carrier. Hydrogen's potential production from renewable energy resources, such as solar, wind using the water electrolysis process has been suggested and investigated in many research studies e.g., [13-16], a various studies have been reported in the literature on geothermal based hydrogen production and heat generation using different technologies [17-20]. A few papers have expounded on hydrogen production from CO_2-based geothermal systems through water electrolysis [21]. The objective of this work is to present a theoretical study of technical, economical and environmental analysis of the implementation an installation of massive hydrogen production using a geothermal system that uses carbon dioxide as a working fluid to power an industrial alkaline electrolyser in In Salah region.

Nomenclature

C	Cost, $
CTA	Total hydrogen production cost, $/kgH$_2$
E	Geothermal energy production, kWh
LEC	Levelized Electricity Cost, $/kWh
LHV	Hydrogen Lower Heating value, 33.31 kWh/kg
M	Hydrogen gas mass produced, kg
N	Number of well
T	Installation life-time, year

Greek letters

η	Efficiency
τ	Discount rate, 6%

Subscripts

EGS	Enhanced Geothermal System
El	Electrolyser
H_2	Hydrogen
i	Investment
max	Maximum