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Valorization of carbon dioxide by conversion into fuel using renewable energy in Algeria

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ABSTRACT

Reducing the emissions of the main anthropogenic greenhouse gases, such as carbon dioxide (CO_2), is one of the major challenges of this century. A partial solution to these environmental problems could be the capture and the conversion of carbon dioxide. The main objective of the present work is to study the opportunities and prospects of recycling carbon dioxide to produce synthetic fuel, particularly methanol, which is a complementary technology to carbon capture and storage (CCS). This methanol will be produced by using several renewable energies, such as solar, wind and geothermal, for the purpose of using it in the transportation sector in Algeria. In 2013, Algeria's total amount of CO_2 emissions (created by energy consumption) was 143 million tonnes. It is estimated that 44.4 million tonnes of CO_2 can be captured from the exhaust of stationary units (factories and power stations) and converted to methanol every year. By adopting this process, approximately 32 million tonnes of methanol can be produced with an energy value of 580,000 TJ. The methanol produced from CO_2 can be used as an alternative transportation fuel. For this reason, the Geographical Information System (GIS) is used to present the spatial distribution of the methanol demand in short and long terms, based on market penetration rates, vehicle fleet and population data. An analysis of the energy balance, environment and economics of CO_2 recycling process is presented. In terms of environmental performance, the reduction in carbon dioxide emissions that come from the transport sector was remarkable in 2045.

Introduction

The global warming, mainly sourced from the human induced emission of CO_2, is one of the major environmental threats that we are facing in the 21st century (Urakawa and Bansode, 2014). The concentration of CO_2 in the atmosphere has been raised from 280 ppm in 1750 (prior to industrial revolution) to 400 ppm today in 2014 (Ganesh, 2015). Globally, the transport sector was responsible for about 61% of world oil consumption and about 28% of total final energy consumption in 2007 (IEA, 2009). Two sectors produced nearly two-thirds of global CO_2 emissions in 2012: electricity and heat generation, by far

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the largest, accounted for 42%, while transport accounted for 23% (IEA, 2014). Governments around the world are setting targets and taking actions to reduce CO_2 emissions.

To reduce CO_2 emissions, the development of technology for fixing and recycling CO_2 emissions must be required in addition to saving energy and converting to alternative forms of energy with lower CO_2 emissions (Takeuchi et al., 2001). At present, the readily available technology to tackle CO_2 associated global warming problem is the CO_2 capture and storage (CCS) process. The CCS technologies could work as transitional technology, decreasing the CO_2 emissions from the energy sector before a transition to less carbon-intensive energy system is achieved. Since 2004, a project to capture and store carbon found in geological formations operates in Algeria, the CO_2 has been compressed, dehydrated, transported, and then injected into the saline water-bearing leg of the producing gas formation in the Krechba Field (the southern Algerian town of In Salah) (Paulleya et al., 2011). As carbon dioxide capture and storage is still in the demonstration phase, other complimentary alternatives have been developed for utilizing carbon dioxide (CO_2) by converting it into chemicals and fuels (Boretti, 2013). This approach is attractive regarding CCS technologies because CO_2 can be transformed into a valuable chemical such as methanol (economic benefit).

The Methanol Economy could, therefore, in principle, be a relatively feasible and affordable path toward replacing oil (Yang and Jackson, 2012). In 1986, Friedrich Asinger has published his book "Methanol - Chemie- und Energierohstoff" (Asinger, 1986). He advocated for the future use of methanol as an energy and chemical feedstock (Bertau et al., 2014). This vision has been rediscovered and refined by numerous scientists. In the book "Beyond Oil and Gas: The Methanol Economy" (Olah et al., 2006a), Nobel Laureate Olah et al., argued for a new approach (the so-called "Methanol Economy") of how humankind can decrease and eventually liberate itself from its dependence on diminishing fossil reserves (oil and natural gas and even coal while mitigating global warming caused by carbon dioxide released by their excessive combustion. An energy economy based around the capture of CO_2 and its conversion to methanol (CH_3OH) (Olah et al., 2006b).

Much research studies have been reported in the literature for the valorization of carbon dioxide. Takeuchi et al., have described and evaluated a representative system, which consists of three technologies such as hydropower, solar thermal, and solar photovoltaic. These technologies were in CO_2 recovery, hydrogen production and methanol synthesis (Takeuchi et al., 2001). Maravelias et al. have describe a novel solar-based process for the production of methanol from carbon dioxide and water where the system utilizes concentrated solar energy in a thermochemical reactor to reenergize CO_2 into CO and then water gas shift (WGS) to produce syngas (a mixture of CO and H_2) to feed a methanol synthesis reactor (Maravelias et al., 2011). In the study of Soltanieh et al., the methanol was synthesized in the unit through captured CO_2 from fossil fuel power plant and produced H_2 from water electrolysis unit using wind renewable energy (Soltanieh et al., 2012).

In 2011, Algeria has developed a national program for the period 2011–2030 to promote concrete actions in the fields of energy efficiency and renewable energy (CDER, 2011). This program leans on a strategy focused on developing and expanding the use of inexhaustible resources, such as solar energy in order to diversify energy sources and prepares Algeria of tomorrow (Boudghene Stambouli et al., 2012). Using renewable energy (solar, wind, geothermal) and CO_2 captured as feedstock to produce renewable methanol is an attractive greenhouse gas reduction option in the longer term. These renewable fuels are compatible to replace petroleum based non-renewable fossil fuels and can be supplied to the transportation sector as a source of energy.

Since the fuel choice has large consequences for the technology and organization of the future transport system, the fuel choice has major impacts for the transition route toward large scale application of methanol fuel cell vehicles MFCVs in Algeria. The use of renewable methanol as fuel for transportation services could be a promising option. This fuel can be made less expensively than almost all other options; it burns more cleanly than petroleum fuels; and, because it is similar to gasoline and diesel fuel, it does not require costly changes in motor vehicles and the fuel-distribution system (Sperling and DeLuchi, 1989). As the world's largest methanol consumer and producer, accounting for 20% of global methanol output, China could play a leading role in a transition to the Methanol Economy (Yang and Jackson, 2012). In Algeria, the methanol is produced from natural gas. In 2013, the total amount of production of methanol was 78,370 tonnes where 75,968 tonnes is exported (Sonatrach, 2013). A transition to a methanol economy is virtually a paradigm shift for the transportation sector.

Modeling future methanol demand is an important issue in understanding a transition to a methanol economy. The GIS-based method is developed to model the spatial distribution of methanol demand based on market penetration rates, vehicle fleet and population data. This approach is applied to study methanol demand and its projection in short and long term in Algeria. This paper details the methanol demand calculations, using GIS process. First, the GIS data sources used in the analysis were listed. Next, the methodology for estimating spatial demand by GIS techniques is described. The results were presented, where methanol demand is estimated under different scenarios for market penetration rates (7%, 17.9%, 32.6%, 52.1%, 73.7%, and 100%). Finally, the main results and some discussions are summarized in the conclusion.

Energetic situation of Algeria

Algeria has abundant oil and natural gas resources. According to OPEC, 2014, Algeria's oil reserves amounted to 12.2 billion barrels in 2013 (OPEC, 2014). It was the third-largest oil reserves in Africa (after Nigeria and Angola) (BP, 2014). These reserves are mainly in the south-eastern part of the country, particularly in Hassi Messaoud Basin, with over 60% of Algeria's proven reserves and Ourhoud field which is located in the Berkine Basin and it is the second-largest oil field after Hassi Messaoud Basin (Gouareh et al., 2015). Algeria is the second largest natural gas reserves in Africa after Nigeria and the tenth