

ALEXANDRIA UNIVERSITY
FACULTY OF ENGINEERING
10th INTERNATIONAL CONFERENCE
"ROLE OF ENGINEERING TOWARDS A BETTER ENVIRONMENT"
(RETBE'14)
15-17 DECEMBER 2014 ALEXANDRIA, EGYPT.

PRODUCTION OF CARBON-NEUTRAL HYDROCARBONS FROM CO₂
AND H₂ IN LIEU OF CARBON CAPTURE AND SEQUESTRATION (CCS)

RACHEL BECK

*Department of Chemical and Biomolecular Engineering, University of Illinois at Urbana-Champaign,
Urbana, IL 61801 USA*

MAGDI RAGHEB

*Department of Nuclear, Plasma and Radiological Engineering, University of Illinois at Urbana-
Champaign, 216 Talbot Laboratory, 104 South Wright Street, Urbana, Illinois 61801, USA.
mragheb@illinois.edu, <http://www.mragheb.com>*

INTRODUCTION

To ensure an environmentally sustainable future, the problem of CO₂ emissions must be addressed by implementing carbon-neutral energy systems. Carbon Capture and Storage (CCS) is a group of technologies designed to capture CO₂ emissions and sequester them in geological formations. However, CCS is currently hindered by high capital costs and technological challenges. This work discusses the potential to capture CO₂ emissions from power plants and chemically combine them with hydrogen from renewable sources to produce carbon-neutral products.

Alternatives to Carbon Capture and Storage

Potentially useful reformed products include methane, methanol, and green biodiesel. Wind, solar, biomass, and nuclear sources show the most future promise as sources of renewable hydrogen. The technological and economic issues involved in the energy input required to produce H₂, capture CO₂, and create hydrocarbons is discussed.

A significant portion of the costly technology of CCS goes toward transporting and sequestering the CO₂ underground. Rather than attempting to store the emissions in geological formations, which is no guarantee against leaks that would release CO₂ into the atmosphere anyway, it may be possible to convert the CO₂ into useful products. For example, CO₂ can be reacted with hydrogen to create hydrocarbons. For instance, the Sabatier reaction could be used to create methane, CH₄. Although the combustion of the product hydrocarbon would release the CO₂ back into the atmosphere, this creates a carbon-neutral, relatively clean-burning fuel cycle.

Methane Production

The Sabatier reaction shown in Eq. 1 ($\Delta H_{298} = -165$ kJ/mol) is a well-established process for producing methane by reacting CO₂ with H₂ over a metal catalyst, the most effective catalysts being nickel and ruthenium.¹¹



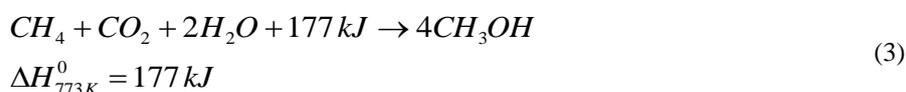
Methanol Production

Another potentially useful product that could be made from reformed CO₂ is methanol, CH₃OH. Methanol is an important chemical feedstock and alternate fuel source, with fewer toxic emissions than gasoline.

A first step involves the formation of synthesis gas via the combined steam and CO₂ reforming of CH₄:

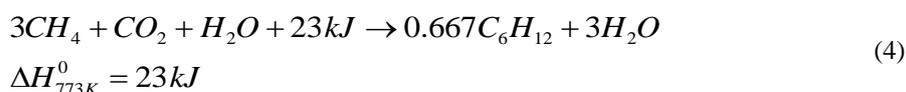


Following the reforming step, methanol is synthesized by reacting the resultant synthesis gas. The overall process can be described as:



Sulfur-free green diesel fuel

The first step involves the reforming of CH₄ to produce synthesis gas while in the second step the resulting synthesis gas is reacted to produce the diesel fuel:



Renewable hydrogen sources

We describe and compare a few methods for producing hydrogen from renewable sources. Advances in wind power have reduced the cost of utility-scale wind electricity to 3-7 cents per kW hr, making wind electrolysis an attractive option. Wind electrolysis involves the wind turning a wind turbine containing an electrical generator, which can power an electrolyzer to dissociate water into O₂ and H₂. A potential advantage of wind electrolysis systems is the improved ability to dispatch electricity; that is, the wind turbine can produce hydrogen to store energy, later using a fuel cell to create electricity in high-demand periods. For wind electrolysis to become cost-effective, there will need to be a decrease in wind electricity prices, increase in electrolyzer efficiency, and an increased effort to integrate wind/electrolyzer systems.

Discussion

If current CO₂ capturing cost could be reduced by 35-40 percent CO₂ and natural gas reforming can be potentially sustainable from CO₂ recovered from flue gases. Wind, biomass, and nuclear show the most future promise as sources of renewable hydrogen. Due to the energy input required to produce H₂, capture CO₂, and create hydrocarbons, this proposal has admittedly a net energy loss. Ultimately, if the cost of renewables can compete with the cost of carbon energy using CCS methods, the departure from fossil fuel dependence will happen all the more rapidly.