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**PRODUCTION OF CARBON-NEUTRAL HYDROCARBONS FROM CO<sub>2</sub>**  
**AND H<sub>2</sub> IN LIEU OF CARBON CAPTURE AND SEQUESTRATION (CCS)**

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## **INTRODUCTION**

To ensure an environmentally sustainable future, the problem of CO<sub>2</sub> emissions must be addressed by implementing carbon-neutral energy systems. Carbon Capture and Storage (CCS) is a group of technologies designed to capture CO<sub>2</sub> 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 CO<sub>2</sub> 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 H<sub>2</sub>, capture CO<sub>2</sub>, and create hydrocarbons is discussed.

A significant portion of the costly technology of CCS goes toward transporting and sequestering the CO<sub>2</sub> underground. Rather than attempting to store the emissions in geological formations, which is no guarantee against leaks that would release CO<sub>2</sub> into the atmosphere anyway, it may be possible to convert the CO<sub>2</sub> into useful products. For example, CO<sub>2</sub> can be reacted with hydrogen to create hydrocarbons. For instance, the Sabatier reaction could be used to create methane, CH<sub>4</sub>. Although the combustion of the product hydrocarbon would release the CO<sub>2</sub> back into the atmosphere, this creates a carbon-neutral, relatively clean-burning fuel cycle.

### ***Methane Production***

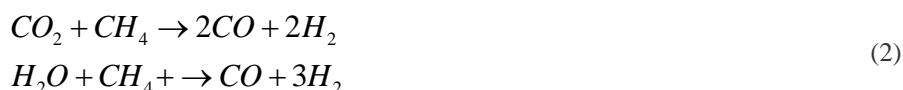
The Sabatier reaction shown in Eq. 1 ( $\Delta H_{298} = -165$  kJ/mol) is a well-established process for producing methane by reacting CO<sub>2</sub> with H<sub>2</sub> over a metal catalyst, the most effective catalysts being nickel and ruthenium.<sup>11</sup>



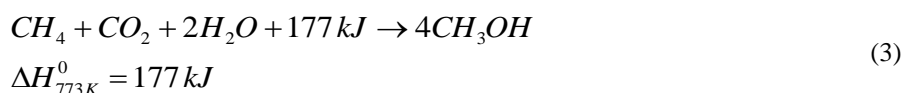
### ***Methanol Production***

Another potentially useful product that could be made from reformed CO<sub>2</sub> is methanol, CH<sub>3</sub>OH. 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 CO<sub>2</sub> reforming of CH<sub>4</sub>:

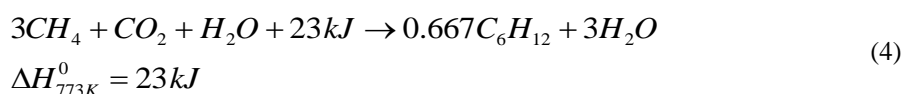


Following the reforming step, methanol is synthesized by reacting the resultant synthesis gas. The overall process can be described as:



### ***Sulfur-free green diesel fuel***

The first step involves the reforming of CH<sub>4</sub> 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 O<sub>2</sub> and H<sub>2</sub>. 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 CO<sub>2</sub> capturing cost could be reduced by 35-40 percent CO<sub>2</sub> and natural gas reforming can be potentially sustainable from CO<sub>2</sub> 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 H<sub>2</sub>, capture CO<sub>2</sub>, 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.