Applications of Biogas in Chemical Energy Storage and Liquid Fuel Production (WP5)

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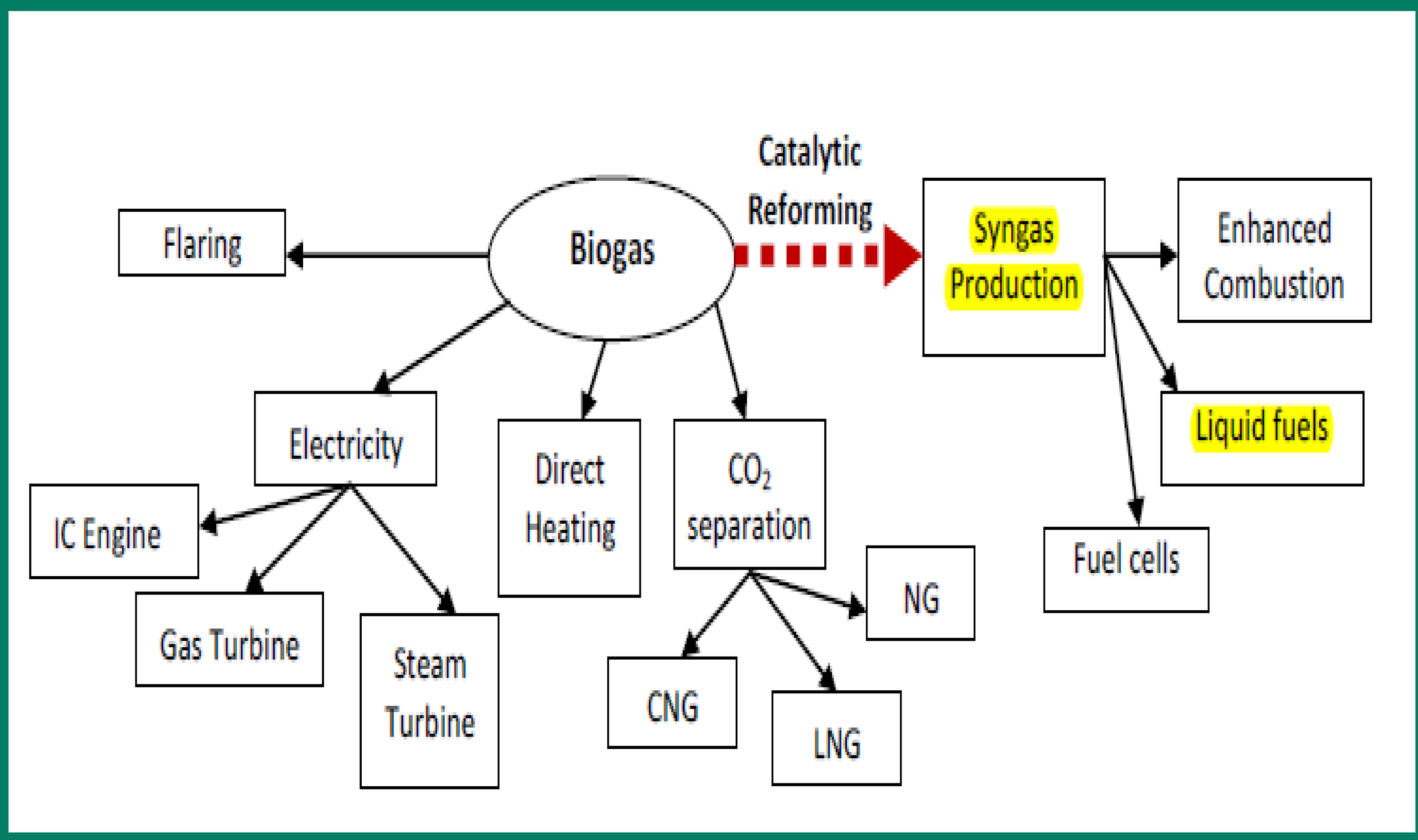
Introduction

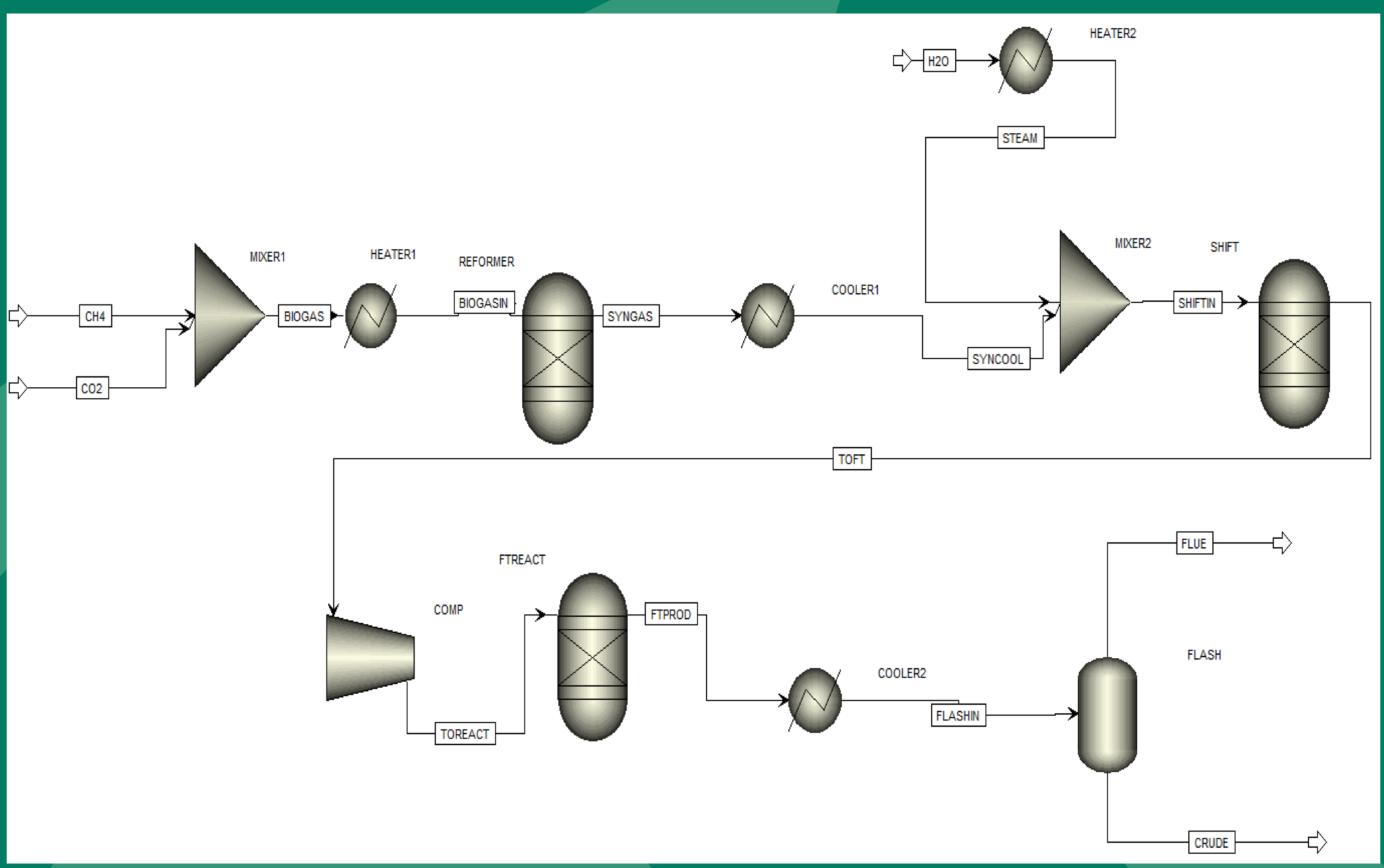
The population will increase to 8.9 billion by the year 2050 and that is a 36% increase from today and the energy consumption is approximated to increase by 77% during that same period. The European union and countries worldwide are shifting to renewable-energy based systems to produce electricity. Doing so would phase out the use of fossil fuels, limit dependency on foreign oil as well as promote green alternatives.

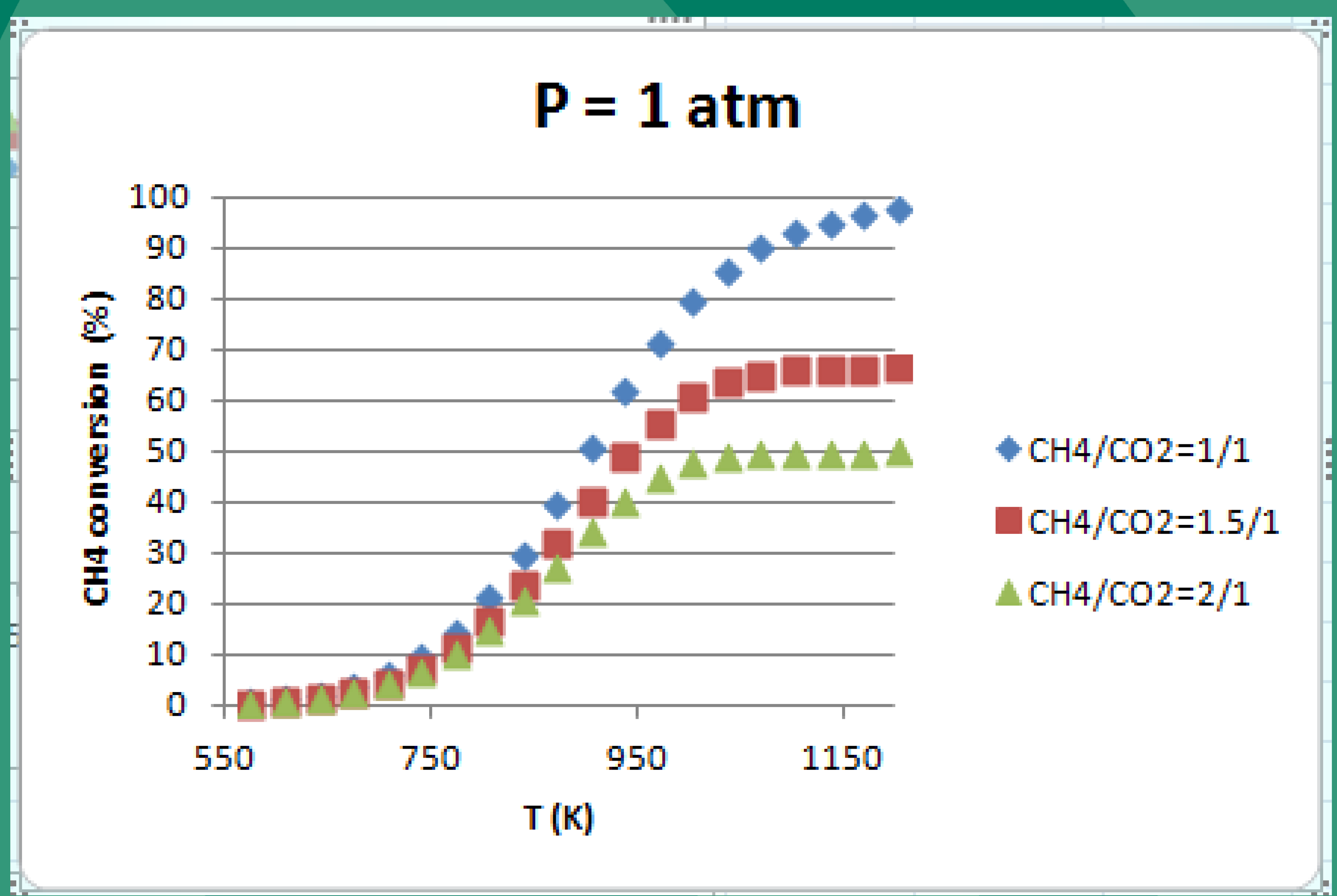
However, this transformation is highly affected by the fluctuating sources such as wind or solar which means that power generation will be limited by their partly predictable availability. In some regions in the EU, due to weather deviations the RE generators are producing a surplus or a shortfall of electricity which needs to be integrated with other energy systems that can offer high predictability and availability. In this respect, energy from biogas is highly advantageous in those regions. A clean model generally has the following percentages; 55-65% methane and 30-45% carbon dioxide

Utilization

One of the main reasons why biogas was not widely used for energy is due to the fact that its high percentage content of carbon dioxide decreases the heating value of the gas mixture. This results in an increased amount of CO, NO_X and unburned hydrocarbons produced when combusted in a turbine or boiler when compared to pure methane or natural gas. For those reasons, biogas was usually flared or burned and released to the atmosphere as carbon dioxide and water without taking advantage of the latent chemical energy. The biogas produced can be cleaned from impurities especially H_2S and upgraded (removal of carbon dioxide) resulting in a pure methane stream that can be later injected into the "natural gas distribution network" or can be used as a compressed natural gas (CNG) or liquefied natural gas (LNG) that is suitable as a form of transportation fuel. It can also be used as a feedstock to different reforming technologies that were previously applied extensively for natural gas reforming. These reforming techniques would require the transformation of biogas to synthetic gas. The production of synthetic gas also known as syn-gas is the most efficient and commercial form of gas to be produced from biogas.







Chemical Energy Storage

Researchers have been looking for ways in order to store biogas in forms that can be later used when electricity supply is less than the demand. They are also investigating different ways to store the excess of wind energy also for utilization when electricity supply is low.

One possible way is using **electrolyzers** that transform water and excess electricity to **hydrogen** which is then stored in hydrogen tanks. The latter hydrogen fuel can be used in a Fisher-Tropsch reactor along with syngas to produce liquid fuel. However, to date electrolyzers are highly expensive. An alternative way is allowing the biogas to undergo dry reforming via the following equation:

$CO_2 + CH_4 \rightarrow 2H_2 + 2CO$

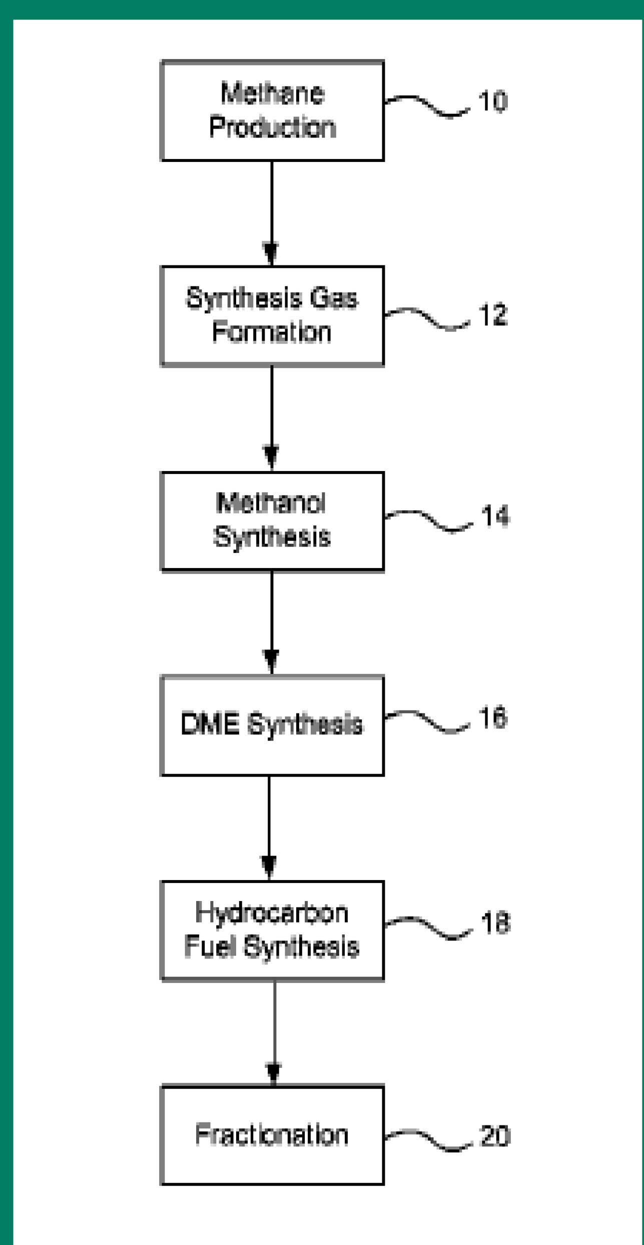
The process produces an $H_2/CO=1$ and reach up to 2 making it a suitable for the production of **methanol** and of **liquid fuel** via Fischer-Tropsch. However, it holds the risk of coke formation on the surface of the catalyst.

Another method is known as **Compressed Air Energy Storage (CAES)**. These power plants are designed to store the excess energy (from wind energy), and whenever electricity is required, the compressed air together with natural gas can be converted back to electricity. In this way, biogas can be used as the source of natural gas and it can aid in shifting the system to a demand-driven one .

Objectives

Liquid fuel production including diesel, gasoline and various other olefins and parrafins via fisher-tropsch seem promising since FT fuels have high energy content and thus can ensure maximum energy recovery. The production of methanol is also worth noting because it is a high energy density hydrogen carrier, which through reforming can be used as a feed for hydrogen powered fuel cells. Also, it can be used as a direct substitute for gasoline or can be uograded to dimethyl-ether DME as a substitute for diesel.

The course of the project will include development of calculations and models to assist the policy of choice. Thermodynamic investigation will also betaken into account when trying to find the most efficient process for maintaining energy density.



FT reactions

Olefins:

$nCO + 2n\ H_2 \rightarrow nH_2O + C_nH_{2n}$

Paraffins:

$nCO + (2n+1)\ H_2 \rightarrow nH_2O + C_nH_{2n+2}$

Water gas shift :

$CO + H_2O \leftrightarrow CO_2 + H_2$

Methanol Synthesis

$CO + 2H_2 \rightarrow CH_3OH$

Water gas shift

$CO + H_2O \leftrightarrow CO_2 + H_2$

DME Synthesis

$2CH_3OH \leftrightarrow CH_3OCH_3 + H_2O$

[1] Corradini et al. United States Patent. Process and System for converting biogas to liquid fuels. Patent no: US 8,378,159 B2 ; February (2013)