BIOGASOLINE PRODUCTION WITH ENGINEERING ECONOMIC ANALYSIS

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1. BIOMASS TO GASOLINE (*i*GASOLINE)

This is a collaborative work of several universities and the research institute INER (http://www.iner.gov.tw) of Taiwan. The goal is to develop the key technologies to converting biomass to gasoline (*i*Gasoline). The framework is depicted in Fig. 1. The *i*Gasoline project consists of torrefaction, plasma gasification, gas cleaning system, syngas refining system, one-step direct dimethy ether (DME) production, and biogasoline production. The first phase of the *i*Gasoline project is the integrated process synthesis and design of plasma gasification of biomass to syngas (BtS), direct synthesis of syngas to DME (StD) and DME to gasoline (DtG). The second phase of the *i*Gasoline project is the development of catalysts used in the DME reactor and the biogasoline reactor. The third phase of the *i*Gasoline project is the construction of pilot plant. We will present the results of the first phase in this symposium. Engineering economic analysis associated with the syngas to gasoline (StG) is also presented.

1.1 Plasma Gasification of Biomass to Syngas (BtS)

The CO_2-plasma torch jet will provide a homogeneous temperature of about 1000^oC to all fractions of the syngas. This results in a complete dissociation of all hydrocarbons, even halogenated, with no indication of recombination. There are no toxic nor carcinogenic organic compounds present in the produced fuel gas because no such compounds can survive at this temperature. This means no formation of volatile organic compounds (VOCs) such as dioxins and furans as are found with other technologies. The goal is to produce syngas with a composition of $H_2 : CO : CO_2 = 2 : 1 : 0.25$.

1.2 Direct Synthesis of Syngas to DME (StD)

In order to analyze the independent chemical reactions involved in the reactor, it is necessary to carry out a study of the chemical reaction stoichiometry. And with a specific syngas feed, the following reactions are found: (1) $CO_2 + H_2 = H_2O + CO$, (2) $CO + 2H_2 = CH_3OH$, and (3) $3CO + 3H_2 = (CH_3)_2O + CO_2$. To gain an insight into the reactor design, we have also utilized the concept of thermodynamics, including equilibrium-constant method and the minimization of Gibbs free energy (Chen, 2012).

1.3 From DME to Gasoline (DtG)

Just as methanol can be converted into gasoline boiling-range hydrocarbon over zeolite ZSM-5 catalyst, the Mobil MTG process (Packer, 2005), DME results in an identical hydrocarbon distribution over the ZSM-5 catalyst. The conversion of DME to biogasoline and water is: $(CH_3)_2O \rightarrow [CH_2.CH_2] + H_2O$, where $[CH_2.CH_2]$ is the average composition of the hydrocarbon product (Lee *et al*., 1995). Our research team currently works on the performance improvement of the ZSM-5 catalyst for the biogasoline production.

2. PROCESS SYNTHESIS AND DESIGN

2.1 From Biomass to Syngas (BtS)

On the basis of 10,000 tonnes per year of biogasoline production, the integrated block flow diagram is depicted in Fig. 2. The process flow diagram of BtS is shown in Fig. 3.

2.2 From Syngas to Gasoline (StG)

The process flow diagram (Fig. 4), is the final configuration which combines the pinch technology with the base-case design for heat exchanger network synthesis in order to compare the energy consumption and capital costs of the process with/without heat integration. Two kinds of software were used in the research—Aspen Plus (Aspen Tech., 2011) and SuperTarget (KBC, 2010). The former was used to implement the process synthesis, design, and simulation; the latter was used to carry out the pinch analysis and the synthesis of heat exchanger network. A cash flow diagram for the StG process is shown in Fig. 5 by using the economic parameters listed in Table 1.

3. CONCLUSION

1. We have described the highlights for the collaborative research on the "*i*Gasoline" project.
2. We have presented a process synthesis and design with a goal of 10,000 tonne/per year of biogasoline for the "*i*Gasoline" project.
3. We have also conducted an engineering economic analysis for the process of syngas to gasoline (StG).

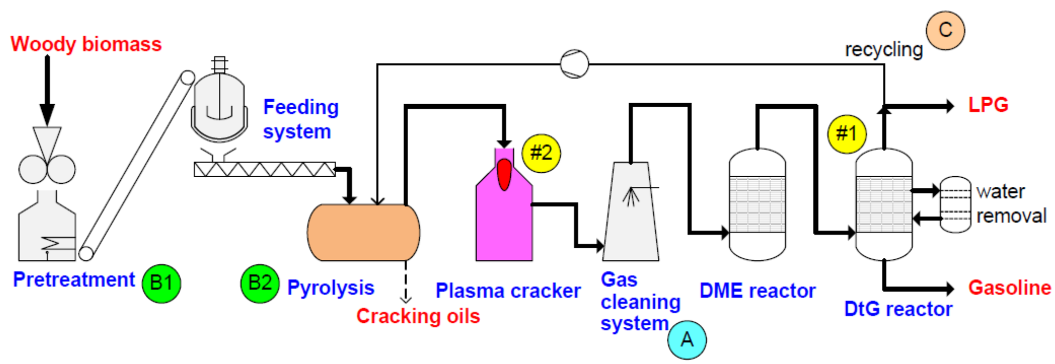

Fig. 1. The framework of Biomass to Gasoline—*i*GASOLINE.

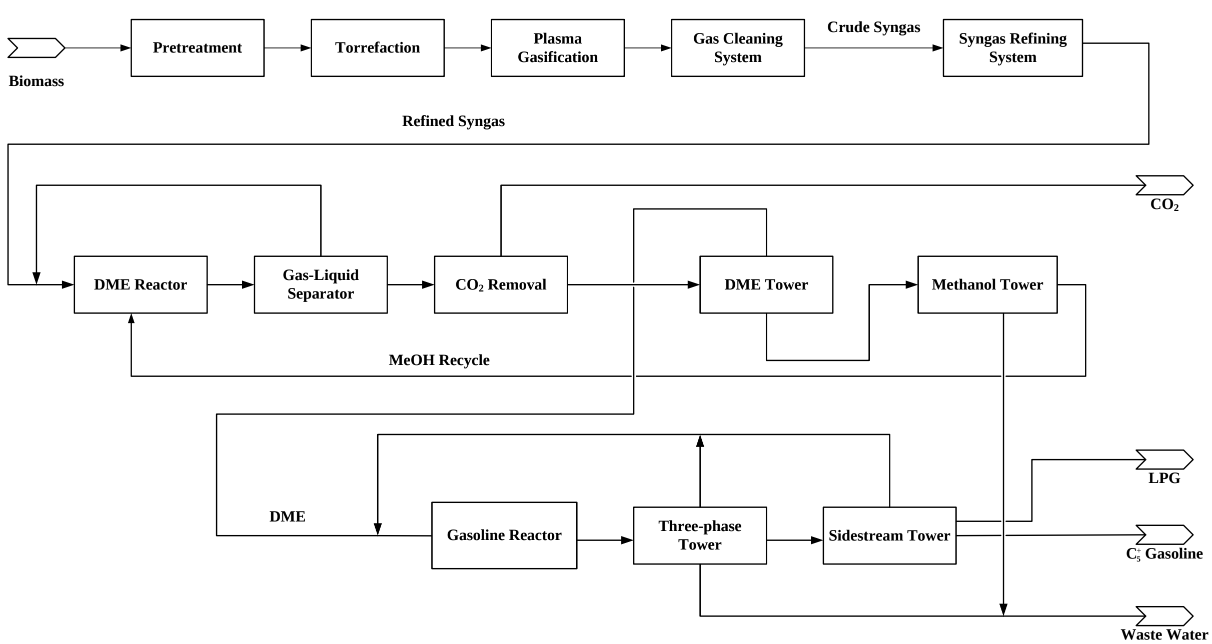

Fig. 2. Integrated Block Flow Diagram for the *i*GASOLINE Project.

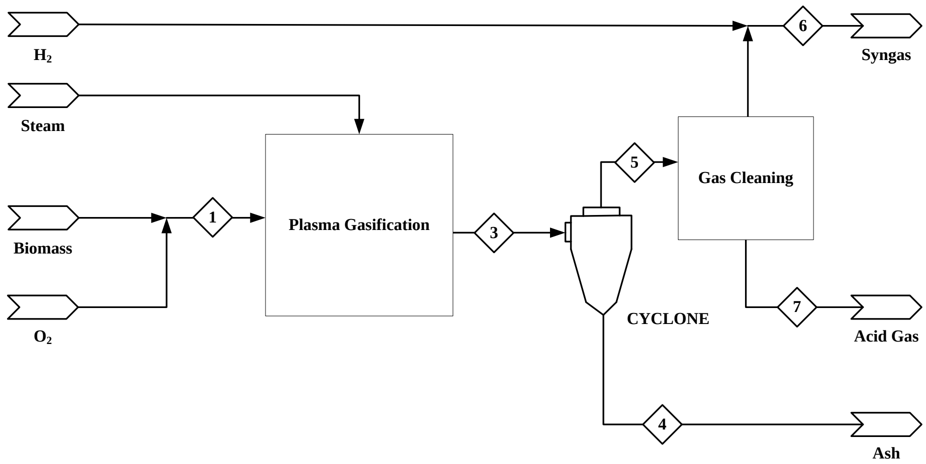

Fig. 3. Process Flow Diagram of BtS.

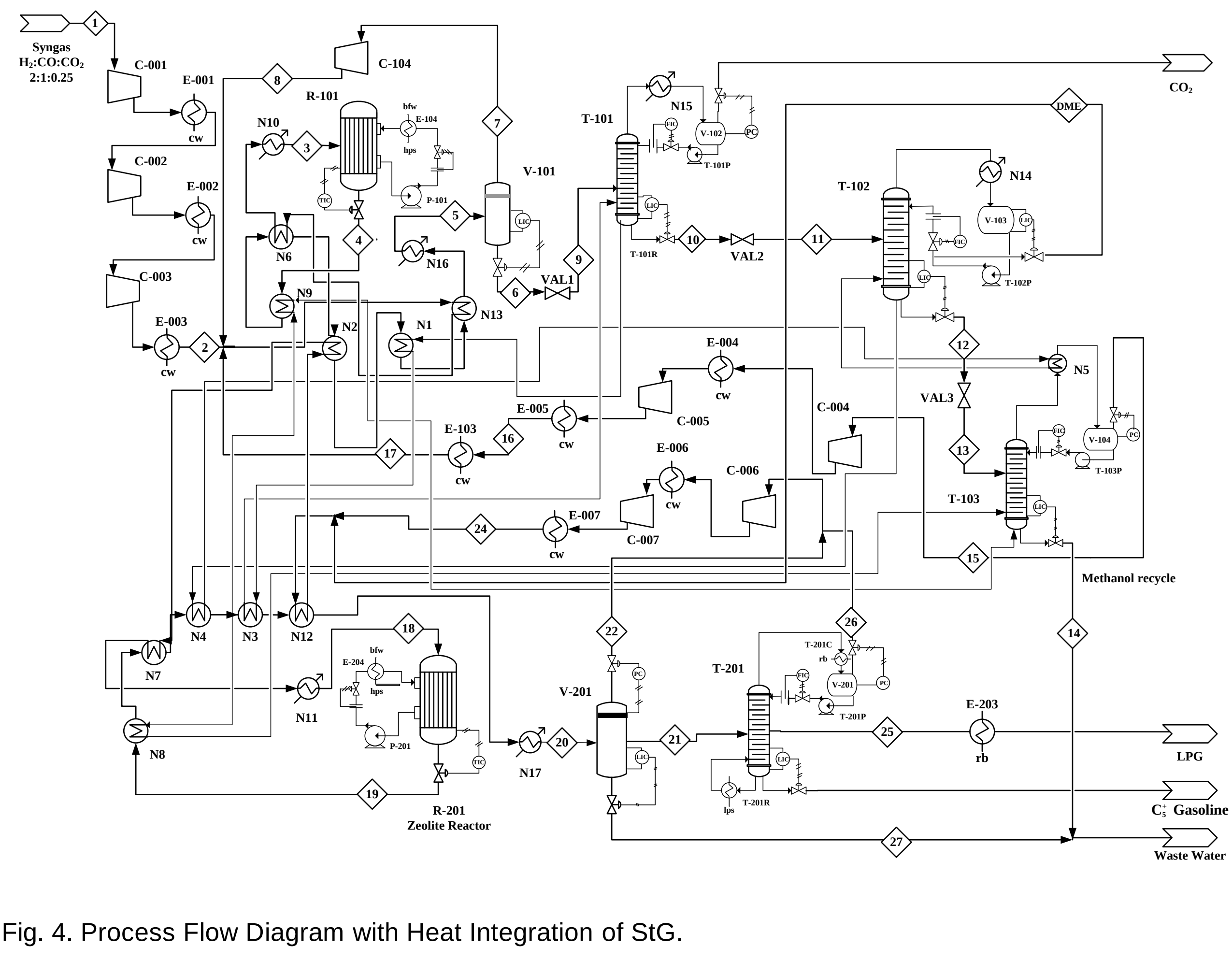

Fig. 4. Process Flow Diagram with Heat Integration of StG.

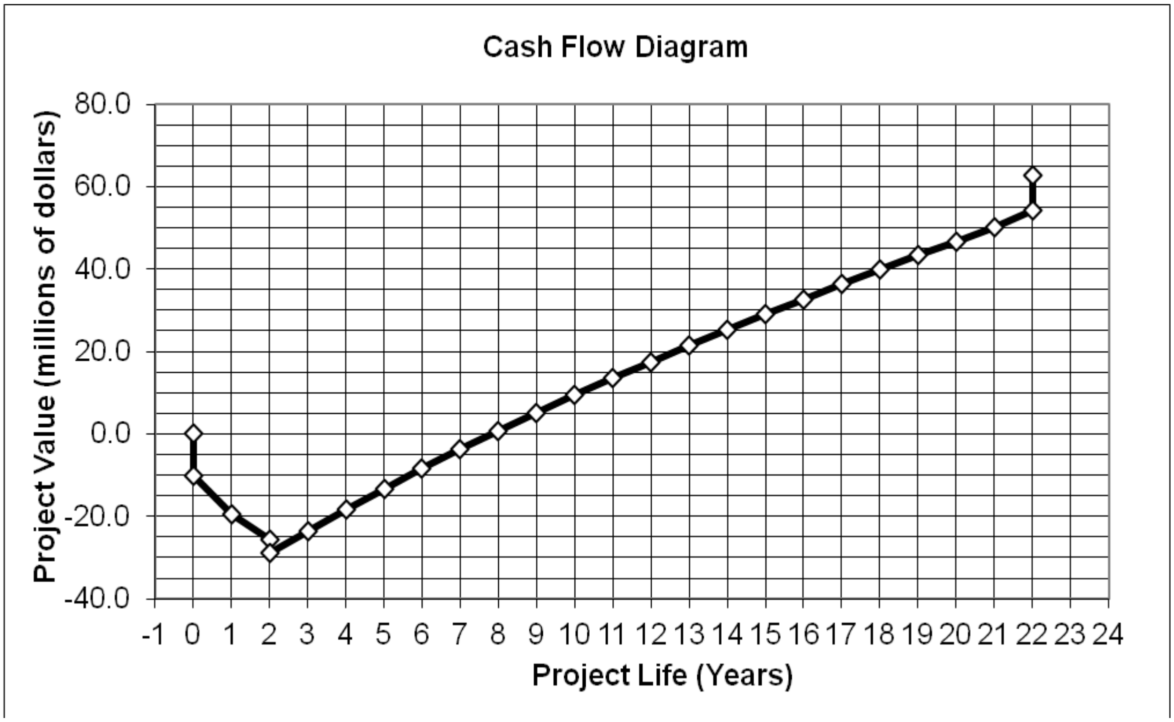

Fig. 5. Cash Flow Diagram of the StG Process.

Table 1 Economic assumptions for discounted cash flow analysis. Working capital and Cost of land are recovered at the end of project life.

Parameter	Value
Land	US$10x10^6
Fixed capital investment during year 1	60% of total fixed capital investment
Fixed capital investment during year 2 (Plant start-up at end of year 2)	40% of total fixed capital investment
Working capital	20% of total fixed capital investment
Taxation rate	17%
Annual interest rate	2%
Savage value of plant	10% of total fixed capital investment
Depreciation	7-year MACRS
Project life	20 years

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