ECONOMIC BENEFITS OF C_2 UTILIZATION IN CHINA

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Resources and utilization of C_2 compounds in China has been reviewed. Transformations of bioethanol feedstock into ethylene, acetylene and ethylene feedstocks into chloroethylene, and ethylene feedstock into ethylene oxide have been discussed, and effects of these processes on the energy utilization and environmental damage have been evaluated. The viewpoints of economic or social benefits have also been discussed.

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INTRODUCTION

With the decrease of available mineral oil resources, the importance of traditional energy resources, such as coal and natural gas, increases and converting C_2 components into higher value products becomes more and more important. This latter is expected to result in economic and social benefits[1].

Chinese economic and social development has been limited due to the shortage of natural resources. The output of Chinese crude oil production has been varied between $1.8x10^8$ and $2.5x10^8$ t per year.[2] Since the Chinese crude oil reservation is about $32.7x10^8$ tons, the known crude oil resources are expected to cover the Chinese demands only for 16 years. Since 52% of the processed crude oil comes from overseas, the Chinese government introduced various policies to increase the energy production efficiencies[3] and to decrease taxes for those companies which turn efforts to use renewable energy resources such as wind, water, C_2, etc.

Nowadays the efficiency of C_2 utilization is very low in China, because most of these resources are fired and discharged into the environment. This latter has a serious negative effect on our health and living, strongly degrades the environment, and causes serious pollution; therefore researchers and engineers turn a lot of effort in the development of this area, focusing on increasing the efficiency of C_2 source utilization with maximal economic benefits.

It is an urgent demand to utilize C_2 sources in a more rational way as simple fuel, involving new processes, which could result in improving the product's value. These new processes could improve the energy efficiency and decrease the environmental pollution as well. In this paper, three important methods are reviewed, namely the production of ethylene, chloroethylene, and ethylene oxide, based on various C_2 sources.

DISCUSSION

Alcohol as feedstock to produce ethylene

Gong Linjun [4] developed a method to produce ethylene using bioethanol as C_2 resource. Effects of the reaction temperature, the concentration of alcohol, and the liquid weight hour space on the yields of ethylene were studied in detail.

Table 1 shows the effect of reaction temperature on the yield of ethylene at 10% feedstock ethanol concentration (mass percentage), 150 °C ethanol input temperature, and 0.3 h^{-1} liquid weight hour space velocity. The yield of ethylene firstly increased then decreased with the increase of the reaction temperature. The maximal ethylene yield (99.8%) was observed at 360 °C.

The effect of ethanol concentration on the yield of ethylene can be shown in Table 2. The reaction temperature, input temperature of ethanol, and the liquid weight hour space velocity were 340 °C, 150 °C, and 0.3 h^{-1}, respectively. Keeping the reaction temperature at 340 °C, the yield of ethylene was proven to be more than 97% between 10 and 70 % ethanol concentration. However, above 95 % ethanol concentration the yield of ethylene decreased to 83.5%.

Table 3 shows the effect of liquid weight hour space velocity on the yield of ethylene at two different ethanol concentrations. The reaction temperature, ethanol concentrations, and the input temperature of alcohol were selected to be 340 °C, 40 and 70%, and 150 °C, respectively. At 0.6 h^{-1} liquid weight hour space velocity the yield of ethylene was more than 98%, but increasing the liquid weight hour space velocity above 0.6 h^{-1}, the yield of ethylene decreased to 92.6%. The ethanol concentration has no significant effect on the ethylene yield in this concentration range.

Acetylene and ethylene as feedstocks to generate chloro-ethylene

Wang Xianzhong[5] developed a method for producing chloroethylene by using a combined gas (acetylene and ethylene) mixture as feedstock with utilization of residual heat of acetylene heater. The feedstocks (acetylene and ethylene) were obtained from Chongqing Chemical Institute. The compositions of C_2 mixture can be seen in Table 4.

The main reactions are the followings.

$$C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2 \quad (1)$$

$$C_2H_4Cl_2 \rightarrow C_2H_3Cl + HCl \quad (2)$$

$$C_2H_2 + HCl \rightarrow C_2H_3Cl \quad (3)$$

Eqn. (1), (2), and (3) can be combined and expressed as Eqn. (4).

$$C_2H_4 + Cl_2 + C_2H_2 \rightarrow 2\ C_2H_3Cl \quad (4)$$

Table 1. The effects of reaction temperature on the yield of ethylene

Reaction temperature (°C)	160	220	240	300	320	360	420
Yield of ethylene (%)	6.9	49.3	67.2	68.9	98.6	99.8	96.5

Table 2. The effect of alcohol concentration on the yield of ethylene

Concentration of alcohol (%)	10	40	70	95
Yield of ethylene (%)	99.8	97.6	98.5	83.5

This method is called “One Heater and Three Gases” procedure. Three gases are acetylene, ethylene, and chlorine. They were purified before use. Acetylene was mixed with hydrogen chloride in the acetylene reactor for producing chloroethylene. Ethylene gas was introduced into the reactor and reacted with chlorine to produce dichloroethane. Dichloroethane was used as feedstock and cracked into chloroethylene and hydrogen chloride. Hydrogen chloride was recycled into the acetylene reactor, and the tail gas of the acetylene reactor could be used to produce methanol, dimethyl ether, ammonia, chloroethylene, and polyvinyl chloride. Chongqing Chemical Institute developed this method (“One Heater and Three Gases”) and could improve the efficiency of the acetylene heater unit with ca. 22.8% and could increase the capacity of acetylene heater and the output of acetylene with about 1.5 times and 10.7%, respectively.[5]

Ethylene conversion to ethylene oxide

Wang Chenggang[6] developed a method to oxidize ethylene directly to ethylene oxide. A fixed-bed tube reactor was evaluated in the framework of a one dimensional pseudo homogenus reactor model. This model was proven to be reliable based on the comparison of calculated and measured industrial results. The activity correction coefficient was calculated by a multi-objective optimization method based on the macroscopic reaction kinetics of silver catalyst. Variations of activity correction coefficients with time were investigated and provided certain theoretic reference for the later operation of production.

Table 3. The effects of liquid weight hour space on the yield of alcohol

Mass percentage of alcohol (%)	40	40	40	70	70	70	70
Liquid weight hour space (h^{-1})	0.2	0.3	0.4	0.4	0.5	0.6	0.7
Yield of ethylene (%)	99.8	99.8	99.8	99.8	99.8	99.5	99.6

Generation of ethylene from bioethanol

Yang Bo [7] developed a new technology for ethylene production from bioethanol using dehydration catalysts. The trend of catalyst development was pointed out according to the problems existed in bioethanol dehydration. China is one of the largest of agricultural countries and has no less than 10 billion tons of biomass (such as corn, potato, cane, and so on), which is converted into about 3 billion ton of bioethanol every year. Bioethanol is a renewable source, which can be transformed directly into ethylene. Ethylene can be produced this way in higher purity and with lower separation and investment costs than the ethylene from mineral oil.

Table 4. Composition of the C_2 raw material, % (v/v)

Composition	Content, v%
C_2H_2	6.0 ~ 7.5
C_2H_4	7.0 ~ 9.0
CO	19.0 ~ 21.5
CO_2	2.4 ~ 2..75
CH_4	9.6 ~ 14.5
H_2	44.5 ~ 49.5
C_2H_6	0.25 ~ 0.5
C_3H_6	1.1 ~ 1.75
C_3H_8	small amounts
N_2	0.3 ~ 0.5
O_2	0.05 ~ 0.2

CONCLUSION

The C_2 sources can be used to produce high value chemicals in China. These C_2 source based methods protect the environment and increase the income of a petrochemical plant. The main benefits are as follows: using coal and protecting the local environment, decreasing fossil fuel consumption, and avoiding greenhouse gas emissions, such as SO_2, NO_x, and CO_2, and total suspended particles. Economic developments are initiated and improved using the reviewed new developments.

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