Potential of Ethanol-to-jet (ETJ) in Accordance with Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

Tadpong Ratanasoponchai[a*], Weerin Wangjiraniran[b]

[a]Energy Technology and Management, Graduate School, Chulalongkorn University, Chaloem Rajakumari 60 Building (Chamchuri 10 Building), M1 Floor, Soi Chula 12, Phayathai Road, Phatumwan, Bangkok 10330, Thailand
[b]Energy Research Institute, Chulalongkorn University, 12th Floor Institute Building III, Phayathai Road Pathumwan Bangkok 10330, Thailand

Abstract

The purposes of this study were to evaluate and determine economic and technical potential of ethanol used for the biojet fuels from Ethanol-to-jet (ETJ) technology, which has been enlisted from 2021 to 2035, whether this can be worth developing to serve the carbon offsetting for CORSIA. The international aviation data were used to determine the overall the biojet's ethanol demand from fuel quantities, ICAO maximum blending ratio acceptance and carbon emission using sensitivity analysis, the total ethanol consumption to determine annually overall ethanol demand excluding biojet fuels, and the quantities of ethanol production in Thailand. The stock from ethanol producer was additionally applied for the investigation of the supply potential of ethanol. The result of this study has revealed that the economic potential under the normal scenario has the potential to develop the technology to serve biojet fuels. Similarly, under the COVID-19 scenario, has also shown the potential to develop this technology to serve this biojet fuels. Regarding the technical potential, under the normal scenario, it was appeared the possibility of the ethanol insufficiency on the long run even including the stock of ethanol producer until the post-period of CORSIA timeframe. Meanwhile, under the COVID-19 scenario revealed that Thailand was possibly produce sufficient ethanol demand after the mid-period of CORSIA timeframe. However, on year 2025-2027 shows that there was a possibility of ethanol shortage due to excessive demand.

Keyword: CORSIA/ Biojet Fuels/ Ethanol/ Ethanol-to-jet pathway/ Sensitivity Analysis/ International Aviation

----

*Corresponding Author: Tadpong Ratanasoponchai
E-mail address: 6282006420@student.chula.ac.th

1. Introduction

Ethanol-to-jet biofuels, does Thailand have potential or worth to invest on or develop Ethanol-to-jet pathway technology to serve Carbon offsetting from International aviation under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)? And does Thailand have sufficient Ethanol production to serve Biojet fuels?

CORSIA or Carbon Offsetting and Reduction Scheme for International Aviation is the mechanism accepted by United Nations Framework Convention on Climate Change (UNFCCC) for global aviation carbon emission, developed by the International Civil Aviation Organization (ICAO) and adopted in October 2016. Its goal is to have a carbon neutral growth from 2020. CORSIA uses Market-based environmental policy instruments to offset CO_2 emissions: aircraft operators have to purchase carbon credits from the carbon market. Starting the Pilot phase in 2021, the scheme is voluntary for all countries until 2027, and Thailand was voluntarily attending this scheme during the Baseline phase since year 2019.

The International Civil Aviation Organization (ICAO) has set ambitious goals for reducing greenhouse gas emissions (GHG) in the aviation sector (ICAO, 2016). These have been managed by the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) (ICAO, 2020), and the use of Alternative Jet Fuels (AJF) is one strategic way to achieve these goals (ICAO, 2017). (Rafael S. Capaz, 2021)

Biojet fuel production is the process of producing renewable liquid fuel for aviation applications. The renewable fuel can be produced from various biomass from plants, animals, wastes, and residues (Cheng Tung Chong, Jo-Han Ng, 2021).

The objective of this study was to analyze the potential of Ethanol in Thailand by evaluating the feasibility of Alcohol-to-jet, Ethanol-to-jet pathway technology along with the sufficiency of Total Ethanol demand, Ethanol production, Ethanol stock and biojet demand. To determine whether the Ethanol supply in Thailand was potentially sufficient to uphold Total Ethanol demand and biojet demand.

2. Methodology

2.1 CORSIA Carbon Offsetting Requirements

The State shall calculate, for each of the operators attributed to it, the amount of CO_2 emissions required to be offset in a given year prior to consideration of the CORSIA eligible fuels: (Annex 16 Vol. IV Part II Chapter 3, 3.2)

$$OR_y = \%S_y * (OE_y * SGF_y) + \%O_y * (OE_y * OGF_y)$$

Where; OR_y=Offsetting requirements in year y; OE_y=CO_2 emissions covered by CORSIA in year y; SGF_y=Sector's Growth Factor; OGF_y = Individual growth factor; $\%S_y$=Percent sectoral in year y; $\%O_y$=Percent individual in year y.

In this study, due to the confidentiality issues, we are assuming the total summation of all international aviation data as 1 operator (1 sector). Thus, the operator's requirement for year y (from 2021) could be written as below:

$$OR_y = OE_y \times \frac{(SE_y - SE_{B,y})^*}{SE_y}$$

Where; OR_y=Offsetting requirements for Operator in year y; OE_y=Operator's CO_2 emissions covered by CORSIA in year y; SE_y=Sectoral emissions, with route-coverage by CORSIA in year y; $SE_{B,y}$=Sectoral emissions in baseline (av. 2019/2020) with route-coverage by CORSIA in year y; *We assumed $\frac{(SE_y - SE_{B,y})}{SE_y}$ as sectoral growth factor (SGF).

For the baseline of CO_2 emissions (the average emission of year 2019 and 2020), the international emission data given by CAAT was used on year 2019 and assumed the growth from year 2019 to 2020 to 4.15% (Kasetsart University, Mechanical Engineering Dpt., Executive Summary, February 2020). The scenario for aviation industry has been predicted that the situation of aviation industry might be recovered to the situation as year 2019 on year 2024**.** Then, calculated the average emission by finding the average emission of year 2019 and year 2020 as the ceiling of CO_2 emission on year 2021 to the end of CORSIA timeframe (year 2035) (Krungsri Research, Industry outlook: Aviation industry year 2021-2023).

2.2 Ethanol Potential Analysis

In this study, the Potential analysis consists of 2 parts, Economic and Technical Potential Analysis.

For Economic Potential Analysis, there were 2 scenarios, normal and COVID-19 scenario to determine whether the Ethanol-to-jet fuels worth/feasible to develop in Thailand under the CORSIA. The input data for Economic Potential Analysis are:

- Jet-fuel price.
- Carbon Credit Price (CDM-based).
- Ethanol-to-jet Technology cost.
- Maximum Blending Ratio for Ethanol-to-jet.
- International Aviation Carbon Emission.

For Technical Potential Analysis, there were also 2 scenarios, normal and COVID-19 scenario to determine whether Thailand Ethanol production is potentially sufficient to serve all Ethanol-to-jet fuels under the CORSIA. The input data for Technical Potential Analysis are:

- Ethanol consumption demand, stock and producer supply.
- Biofuels (ULG) consumption projection.
- Maximum Blending Ratio for Ethanol-to-jet.
- International Aviation Carbon Emission.

2.3 Sensitivity Analysis/Scenario Analysis

Sensitivity analysis is the tool to gauge how the inference originating from a model is dependent upon the assumptions and parameters feeding into it.

Scenario analysis is a qualitative method to analyze future events by considering possible outcomes (Duinker & Greig, 2007).

The usage of scenario analysis is not limited by hypotheses, so it is flexible enough to analyze and forecast uncertain development. Scenario analysis considers potential conditions and emergencies as many as possible and provides evidence for decision-makers as much as possible (Fan Zhang, 2021).

In this study, there were 2 scenarios for Economic Potential Analysis, normal and COVID-19 scenarios and 2 scenarios for Technical Potential Analysis, Clear and Cloud scenarios. These scenarios explained as follow:

Normal scenario (N), indicates the International Carbon Emission normally without COVID-19 pandemics involved. This scenario determines Total Ethanol from biojet and International aviation emission under Normal situation without COVID-19 influenced.

COVID-19 scenario (C), indicates the International Carbon Emission under the COVID-19 pandemics concurrent. This scenario determines Total Ethanol from biojet and International aviation emission under the COVID-19 pandemics concurrent.

Clear scenario (1), indicates energy consumption behavior which people is changing their lifestyle with seriously concern on environment. Digitalization becomes indispensable. Self-sustain & prosumer are the majority of transformation. Economic is driven mainly by new S-curve. Bio & Circular economies are growing. Energy business is moving toward market competition. Sustainability & 2DC target become the priority for national policy. (ERI & PTT, Thailand Energy Scenario towards Sustainability 2050)

In other words, this scenario was written based on E20 ethanol blending ratio on gasoline demand based. (ERI & PTT, Thailand Energy Scenario towards Sustainability 2050)

Cloud scenario (2), indicates energy consumption behavior which people lifestyle is changing gradually in accordance to digitalization trend. Clean & potential tech disruption are growing so fast, but still cannot take the majority. No significant structural changes in economy, industry, energy business. Impact on pollution & GHG emission is getting worst.International regulation with environment concern come in force. Current policies on clean & smart energy come in place based on energy security. (ERI & PTT, Thailand Energy Scenario towards Sustainability 2050)

In other words, this scenario was written based on ethanol-target based as mentioned on AEDP2018. (Ministry of Energy, AEDP2018, Oct 2020)

In this study we have a total of 4 scenarios, N1, N2, C1 and C2. We called N1 as Normal-clear scenario, which means the Emission and biojet demand were based on Normal Scenario and Total ethanol consumption was based on Clear Scenario. And the other scenarios were following the same.

Each of the input parameters will be varied as follow:

- Jet-fuel price, considered on Flat price rate and US-EIA Jet-fuel price projection rate.
- Carbon Credit Price (CDM-based), considered on Max. and Min. price per tCO_2e.
- Ethanol-to-jet Technology cost, considered on Max. and Min. technology cost per liter.
- Maximum Blending Ratio for Ethanol-to-jet and International Aviation Carbon Emission, considered on normal and COVID-19 scenario to predict the total jet fuels under the CORSIA, then using Maximum Blending Ratio for Ethanol-to-jet from ICAO to calculate back to Maximum Ethanol quantities.
- Ethanol consumption demand, calculated by using the production target on year 2035, published by OCSB.
- Ethanol stock and producer supply, after year 2020, the stock was assumed to be remained the same as year 2020 until 2035.
- Biofuels (ULG) consumption projection, calculated by using the ratio of Ethanol consumption in ULG on each scenario, and total ethanol

demand on year 2018 to July 2021. Then, find the average ratio of each case. The calculated ratio will be used as divisor for each respective case and scenario.

3. Results and Discussion

3.1 The Prediction of Carbon Offsetting Requirements with Maximum Ethanol demand for biojet fuels.

The Prediction of Carbon Offsetting Requirements indicates the amount of Carbon Emission under the CORSIA from year 2021 to 2035, and the baseline emission, which calculated by the average of the summation of the emission on year 2019 and predicted emission on year 2020. The emissions on each year which exceed the baseline emission must be offsetting using Carbon Credit scheme accepted by the ICAO.

The Predicted Carbon Emission considered in 2 scenarios, under the Normal scenario, and under the COVID-19 scenario.

Under these scenarios, assuming the constant aviation growth of 4.15% until year 2035 for Normal scenario, and assuming the aviation industry status to be recovered as year 2019 on year 2024 given the constant aviation growth of 4.15% for COVID-19 scenario. The emission for each scenario and baseline emissions have been predicted as shown on Figure A and B.

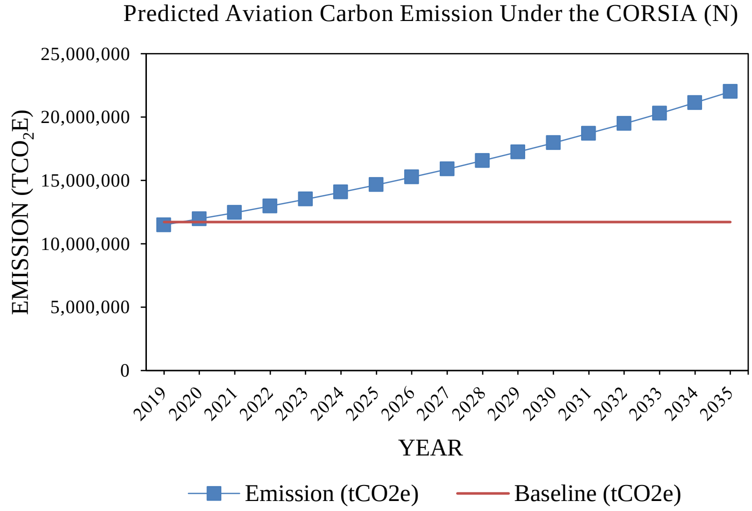

Figure A. The predicted amount of Carbon Offsetting Requirements and Baseline Emission under the CORSIA (N)

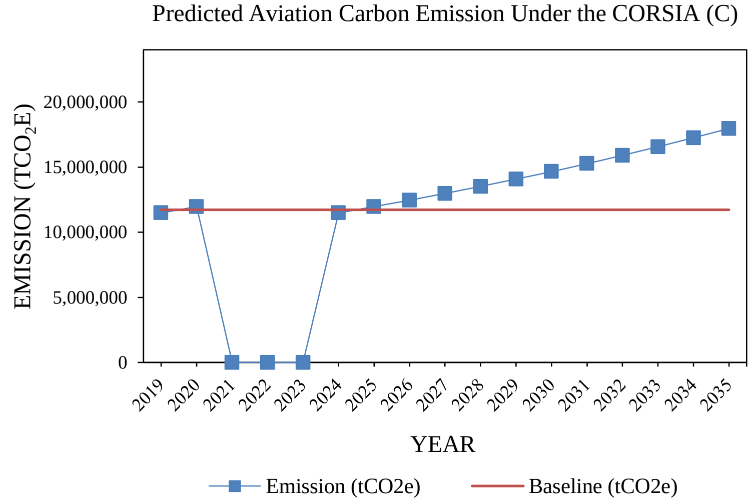

Figure B. The predicted amount of Carbon Offsetting Requirements and Baseline Emission under the CORSIA (C)

3.2 Prediction of overall Ethanol consumption

The Prediction of overall Ethanol consumption indicates overall demand excluded Ethanol-to-jet fuels in order to evaluate the sufficiency of Ethanol in Thailand. In this study, there are 2 assumptions for prediction, using the ratios to be predicted as follow:

- The Ethanol from ULG Simulation (Clear scenario (1)) : Total Ethanol consumption ratio
- The Ethanol from ULG Simulation (Cloud scenario (2)) : Total Ethanol consumption ratio

The overall Ethanol consumption was predicted by using the average ratio from each assumption from January 2018 to July 2021. These ratios were used as divisor for each assumption in order to calculate total overall Ethanol consumption. The Total ethanol consumption based on Clear scenario on Y2035 was 2,530 Million Litres and 2,580 Million Litres on Cloud Scenario.

3.3 The Economic Potential of Ethanol

The Economic Potential of Ethanol was considered on various dimensions. In this study, the Economic Potential was focused on the Jet-fuel price, the Ethanol-to-jet (ETJ) Technology cost, and the Carbon Credit price. By varying ETJ Technology cost and Carbon Credit Price compared with Jet-fuel Flat-rate price and Jet-fuel with US-EIA Projection rate price to determine whether the Ethanol-to-jet fuels was worth developing or investing. The conclusion of Economic Potential of Ethanol has been summarized as shown on Figure C and D.

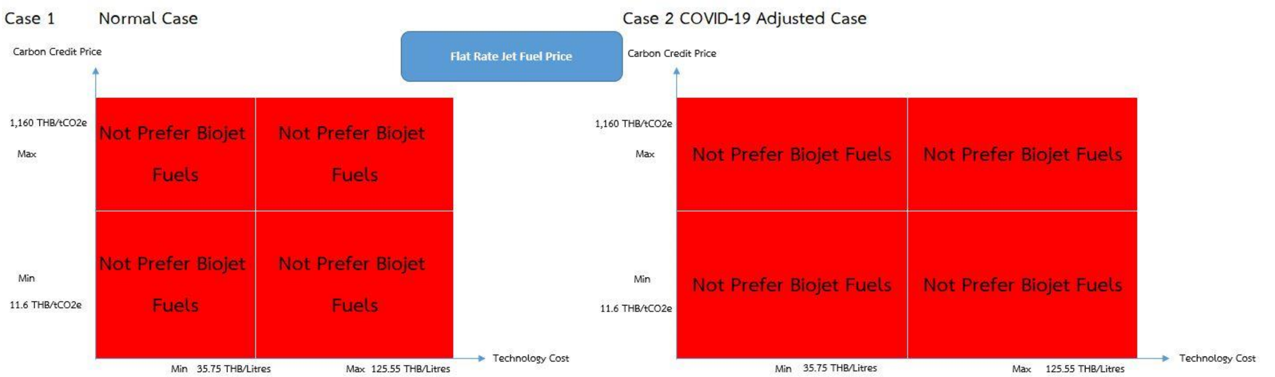

Figure C. The Economic Potential of Ethanol under each scenario by considering Flat Rate Jet fuel Price.

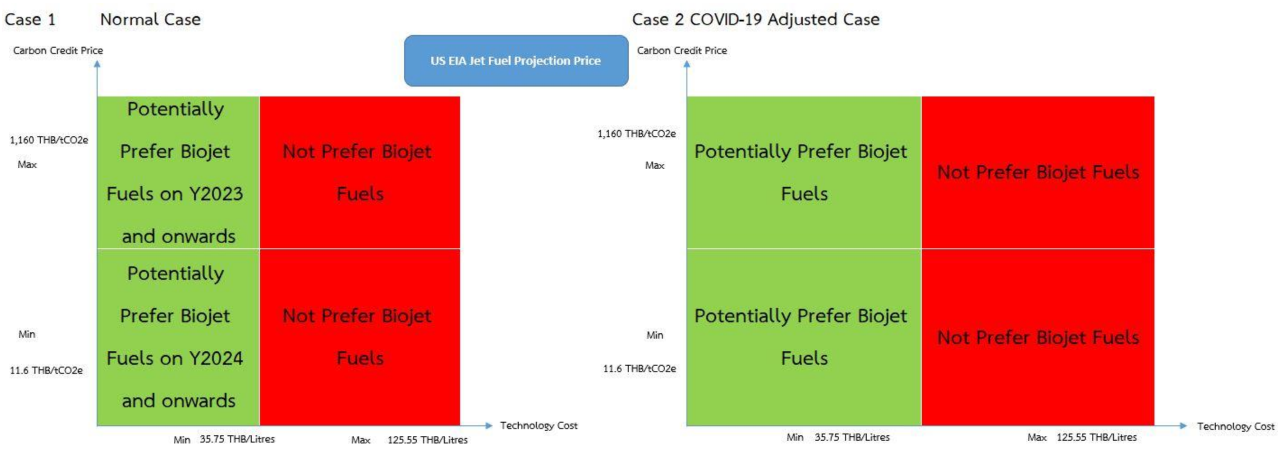

Figure D. The Economic Potential of Ethanol under each scenario by considering US EIA Jet fuel Projection Price.

3.4 The Technical Potential of Ethanol

The Technical Potential of Ethanol was considered on the sufficiency of Ethanol demand and Ethanol production, ethanol supply and stock. By comparing the Ethanol supply (from Ethanol Production and Producer Stock) and

Total Ethanol demand (from overall Ethanol consumption and Total Ethanol for Biojet), the results was shown on Figure E to H.

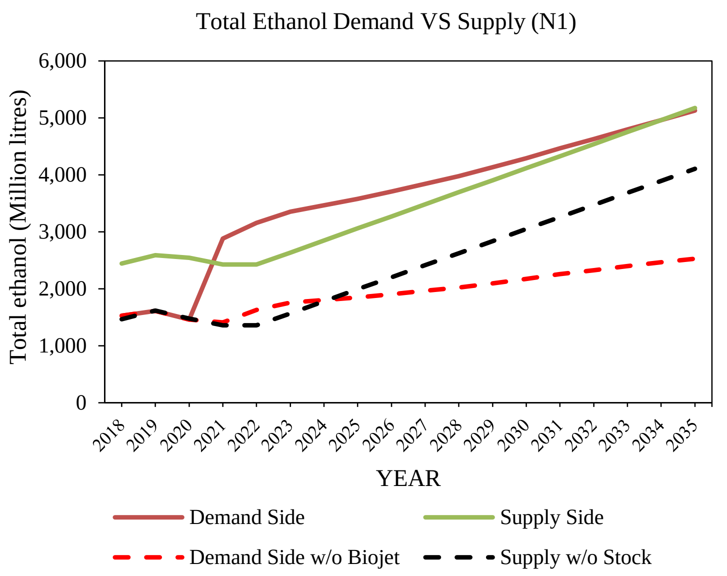

Figure E. The Technical Potential of Ethanol with the consumption prediction under Ethanol use in ULG and Total Ethanol consumption Ratio (N1)

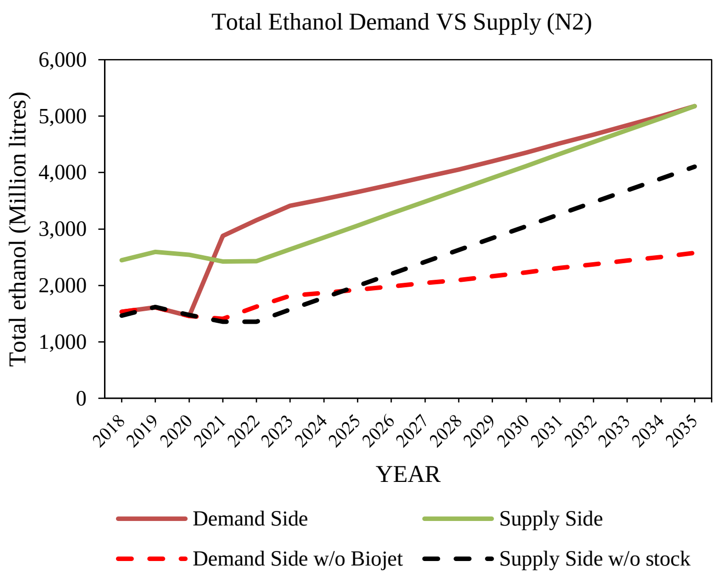

Figure F. The Technical Potential of Ethanol with the consumption prediction under Ethanol use in ULG and Total Ethanol consumption Ratio (N2)

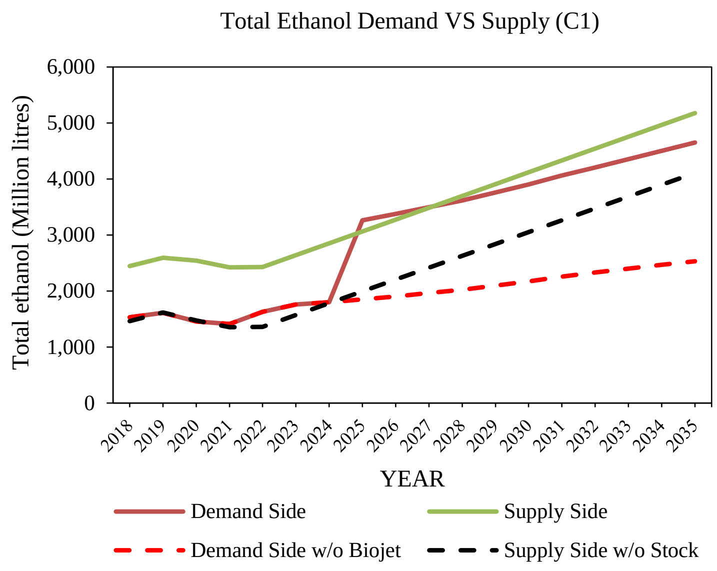

Figure G. The Technical Potential of Ethanol with the consumption prediction under Ethanol use in ULG and Total Ethanol consumption Ratio. (C1)

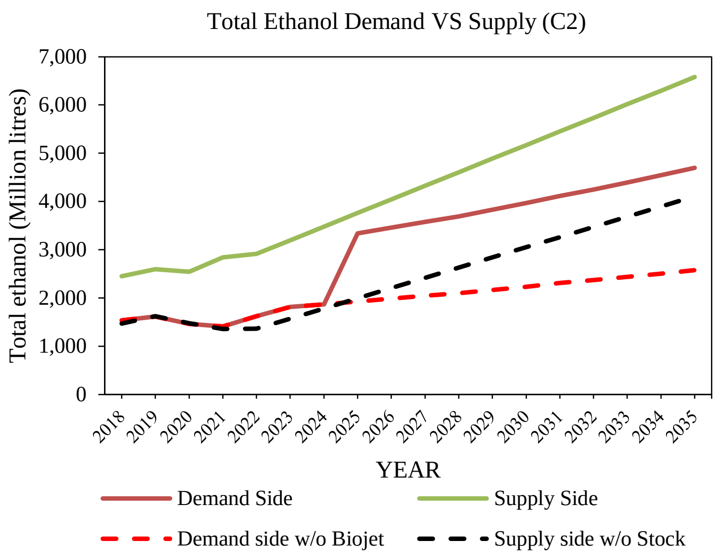

Figure H. The Technical Potential of Ethanol with the consumption prediction under Ethanol use in ULG and Total Ethanol consumption Ratio. (C2)

4. Conclusions

In this study, the Potential of Ethanol was evaluated by considering the Economic Potential of Ethanol, and the Technical Potential of Ethanol. The conclusions upon the scenarios could be as follows:

CDM Carbon credit price (1,160 THB/tCO_2e) on year 2023 and onwards. There were cases that the Ethanol supply cannot hold upon overall Ethanol demand on the post period

Normal Scenario Perspective (N-Perspective) – The Ethanol-to-jet Technology was potentially preferred upon the possibly lowest technology cost (35.75 THB/Litre) on year 2024 at the Minimum CDM Carbon credit price (11.6 THB/tCO_2e) and at the Maximum of CORSIA timeframe, the ethanol supply might not be sufficiently served overall ethanol demand.

COVID-19 Scenario Perspective (C-Perspective)-The Ethanol-to-jet Technology was potentially preferred upon the possibly lowest technology cost (35.75 THB/Litre) with Minimum and Maximum Carbon Credit Price (CDM) (11.6-1,160 THB/tCO_2e). There was some case that show ethanol supply might be shortage. However, the ethanol supply can hold upon overall Ethanol demand when passing the mid-CORSIA timeframe period.

Acknowledgements

I would like to give my gratitude to CAAT for providing us the International Aviation data, as well as DEDE whose publish the ethanol production data. This study could not have done without these data.

References

CAAT, Aviation Fuel consumption and Emission Data Year 2019, 18 February 2021.

Cheng Tung Chong, Jo-Han Ng, Biojet Fuel in Aviation Applications, Chapter 2 - Biojet fuel production pathways, 2021.

Department of Alternate Energy Development and Efficiency, Monthly Ethanol Database, year 2018 to July2021.Available:https://www.dede.go.th/ewt_news.php?nid=55608&filename=index [Accessed on 16 September 2021]

Department of Mechanical Engineering, Kasetsart University, Executive Summary, Sustainable Aviation Biofuel Study, February 2020. Available:http://e-lib.dede.go.th/mm-data/BibA11646_%E0%B8%A3%E0%B8%B2%E0%B8%A2%E0%B8%87%E0%B8%B2%E0%B8%99%E0%B8%89%E0%B8%9A%E0%B8%B1%E0%B8%9A%E0%B8%AA%E0%B8%B8%E0%B8%94%E0%B8%97%E0%B9%89%E0%B8%B2%E0%B8%A2.pdf. [Accessed on 16 September 2021]

EASA, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), Available: https://www.easa.europa.eu/eaer/topics/market-based-measures/corsia [Accessed on 16 September 2021]

Energy Research Institute & PTT, Thailand Energy Scenario towards Sustainability 2050, Diesels and ULG consumption model and scenarios, 15 July 2020.

ICAO Secretariat, ICAO Regional Workshop on CORSIA, Session 6: CORSIA Offsetting Requirements.

ICAO. Annex 16 Vol.4 SARPs Oct 2018, CO2 offsetting requirements Part 2 Chapter 3.2 (p. II-3-2).

Krungsri Research, Industry Outlook: Aviation Industry Year 2021 to 2023, Available: https://www.krungsri.com/th/research/industry/industry-outlook/logistics/air-transport/IO/io-Air-Transport-21 [Accessed on 16 September 2021]

Ministry of Energy, Alternate Energy Developing Plan 2018 (AEDP2018), October 2020.

Office of the Cane and Sugar Board, Ministry of Industry, Ethanol situation (September 2018)

Rafael S. Capaz, The carbon footprint of alternative jet fuels produced in Brazil: exploring different approaches, 2021.

Thailand Greenhouse gas Organization, Carbon Market, Carbon Credit Price (CDM) Available: http://carbonmarket.tgo.or.th/index.php?lang=TH&mod=Y2hhcnQ=&action=bGlzdA== [Accessed on 16 September 2021]

US Energy Information Administrative, Annual Energy Outlook 2021, Table 3. Energy Prices by Sector and Source, Jet Fuel Price Projection. Available: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2021&region=1-0&cases=ref2021~aeo2020ref&start=2019&end=2050&f=A&linechart=~~ref2021-d113020a.29-3-AEO2021.1-0~aeo2020ref-d112119a.29-3-AEO2021.1-0&map=aeo2020ref-d112119a.3-3-AEO2021.1-0&sourcekey=0 [Accessed on 16 September 2021].