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ANALYTICAL HIERARCHY PROCESS (AHP) MODEL FEEDSTOCK SELECTION ON PRODUCING THE SUSTAINABLE AVIATION FUEL

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ABSTRACT

Global energy business is shifting towards more sustainable alternatives fuels due to climate change issue. Countries, companies, and associations start to adopt energy sources with less emission and carbon footprints in their business portfolio, including the introduction of Sustainable Aviation Fuel (SAF) in the aviation industry. Indonesia had created regulation in SAF utilization as blend component in Jet Fuel by the Energy & Mineral Resources Ministry Regulation No.12/2015: 2% (2016), 3% (2020) and 5% (2025). Considering the projected domestic demand of Jet Fuel 6.730.000 KL in 2030, requirement of SAF in Indonesia will reach 337.000 KL. In the contrary, there is no current SAF production in Indonesia despite of its potential feedstock for SAF such as Crude Palm Oil (CPO) Refined Bleached Deodorized Palm Kernel Oil (RBDPKO), or Used Coking Oil (UCO). The research analyzed the business aspect of SAF product development, especially bio-feedstock selection. This paper selected the most optimum feedstock for SAF by Analytical Hierarchy Process (AHP) method with 5 selection criterias: feedstock availability, feedstock price, required capital expenditure (CAPEX), profitability and SAF marketability. A base scenario of "highly regulated and fastly adopted SAF" is selected as the reference of developing the strategy. This scenario is indicated by early warning signs such as establishment of GHG emission reduction framework, establishment of incentives framework and high SAF demand from airlines.

INTRODUCTION

Indonesia's commitment to the Paris Agreement has shown significant forward steps with the recent developments in the adoption of sustainable aviation fuels. As a part of its Nationally Determined Contribution (NDC), Indonesia had pledged to reduce greenhouse gas emissions by 29% on its own or up to 41% with international assistance by 2030, in alignment with the Paris Agreement's global objectives (Suroso et al., 2022; Wijaya et al., 2017). This is further represented in the National General Energy Roadmap (*Rencana Umum Energi Nasional*/RUEN) which details the energy source mix including from new and renewables (Hartono et al., 2023; Maulidia et al., 2019).

The aviation sector, representing a significant contributor to global emissions, emerged as a focal point for Indonesia's green transition strategy (Arens et al., 2021; Fragkos et al., 2021). With over 17,000 islands and a rapidly expanding middle class that increasingly travels by air, the nation's aviation sector plays a pivotal role in its carbon footprint. Thus, the Ministry of Energy & Mineral Resources mandated the periodic increasing mixture of bio-based aviation fuel mixture in the Jet Fuel through Regulation No.12/2015: 2% (2016), 3% (2020) and 5% (2025). Considering the projection of Jet Fuel demand 6.730.000 KL in 2030, the requirement of bio-based aviation fuel will reach 337.000 KL at the same year.

Table 1. Projection of Jet Fuel and Bio-based Aviation Fuel Demand

	2023	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Jet Fuel Demand - Projection, Million KL	3.35	5.34	5.80	5.98	6.15	6.38	6.56	6.73
Bio-based Fuel Mandate, %	3.0	3.0	5.0	5.0	5.0	5.0	5.0	5.0
Bio-based Fuel Demand, Thousand KL	131	160	290	299	308	319	328	337

In accordance with International Civil Aviation Organization (ICAO) programe named Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), utilization of drop-in fuel produced from bio-based feedstock which is later known as Sustainable Aviation Fuel (SAF) is the current best option for reducing emissions from aviation industry while minimizing investment on changing the current airplane, pilot training, or other related investment (Bauen et al., 2020; Prussi et al., 2019). From this program, ICAO is targeting 50% emission reduction from aviation industries by 2050 (ICAO, Annex 16 - Environmental Protection, Volume IV, 2018). To achieve this target, ICAO created the criteria for eligibility of SAF production feedstock which should reduce at least 10% of the conventional fossil-based jet fuel (ICAO, 2021). This includes several bio-based feedstock which are abundance in Indonesia such as Crude Palm Oil (CPO), Refined Bleached Deodorized Palm Kernel Oil (RBDPKO), and Used Cooking Oil (UCO).

Despite of the establishment of government regulation and large potential of bio-based feedstock mentioned above, currently there is no production of SAF in Indonesia. This is due to the high price of SAF compared to conventional Jet Fuel and lack of restrictive domestic policy to drive airlines to adopt SAF thus they are still utilizing conventional Jet Fuel (IATA, 2022). On the other hand, a very restrictive regulation had been made by several countries such as Renewable Energy Directive II (RED II) by European Union (EU) which restricts usage of palm oil derivative in the renewable fuels, including SAF (Makahekum & Arfani, 2021). Hence, fuel producer shall consider these factors when determining the strategy for investing in SAF production facilities. One of the key factor of the strategy is determining the bio-based feedstock to be used in the SAF production (Briassoulis & Giannoulis, 2018; Hildebrandt et al., 2021; Koutra et al., 2018). Therefore, the research analyzed the business aspect of SAF product development, especially bio-feedstock selection. Analytical Hierarchy Process (AHP) method with 5 selection criteria: feedstock availability, feedstock price, required capital expenditure (CAPEX), profitability and SAF marketability to analyze 3 possible feedstock: RBDPKO, CPO and UCO. This research did not include detailed technological aspects of SAF production including the technological advancement of various SAF production methods. The researchers hoped to give more insight into SAF business implementation and contribute to the company on developing strategic plan for SAF production in Indonesia.

METHOD

Scenario Planning Development

Through research and development (R&D), a Scenario Planning approach is utilized rather than simple Forecast Planning method. The Scenario Planning method allows to evaluate all the factors that influence the goal comprehensively compared to simple Forecast Planning which can only determine several deviations from the goal.

Figure 1. Forecast Planning vs Scenario Planning

Several steps with each conceptual framework are required to construct the Scenario Planning including the determination of driving forces and critical uncertainties, developing the scenario planning framework, and select several scenarios to be rigorously analyzed. The overview of Scenario Planning flow is depicted below.

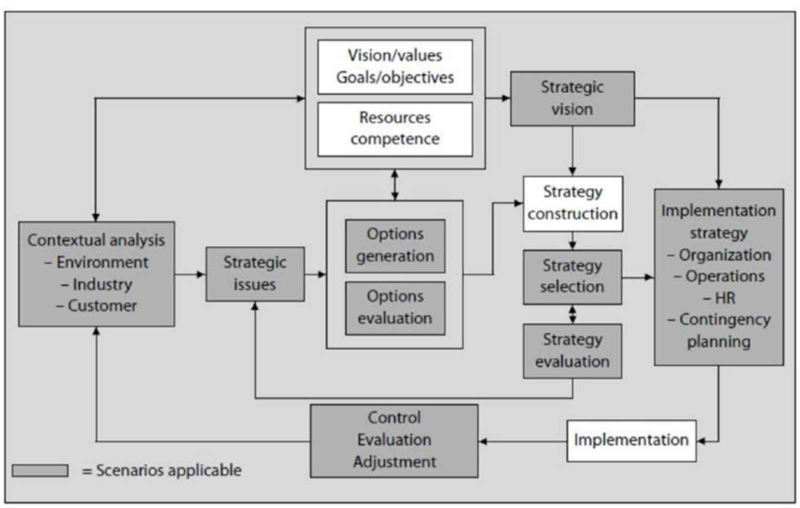


Figure 2. Scenario Planning Flow

To develop the contextual analysis and strategic issues, an Outside-In Approach framework will be used. This approach results in two critical uncertainties which lead to the primary driving forces which affect the future reality scenarios. A scenario development framework is then developed to analyze four possible scenarios and their respective mitigation strategy options. Input from internal and external data is also utilized to further refine the applicable mitigation strategies. An AHP methodology is then implemented to construct, select, and evaluate the best strategy from the options identified. Finally, implementation steps required to bring the best strategy into reality are then listed as the guidance to the company to execute the chosen strategy.

Analytic Hierarchy Process (AHP) Framework

From the Scenario Development process, several strategies are developed. The options of feedstock selection are then listed and compared to each other by implementing the AHP Framework to determine the best feedstock for SAF development. The AHP Framework is depicted below:

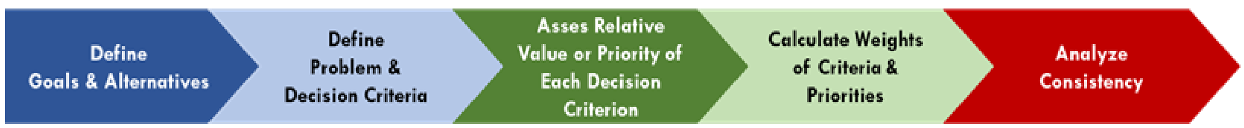


Figure 3. AHP Framework Flow

The consistency is checked by utilising the following equation:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

In which:

CI : Consistency Index

λmax : Largest Eigenvalue of a positive reciprocal pairwise comparison matrix of size n

n : Size of Matrix (number of options)

RI : Mean Random CI listed (as following)

Table 2. Mean Random CI

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Finally, selected scenario will be evaluated economically through analysing its NPV and IRR. The Investment Cost for the project is based on AACE Class V methodology on determining capital cost investment. Revenues and costs are calculated based on experience on previous projects, market intelegence, and stadard practices.

$$DCF = (1 - t)(S - C) + D$$

$$PV_n = \frac{DCF}{(1 + r)^n}$$

$$NPV = \sum_{n} PV_n$$

$$IRR = r \ at \ NPV = 0$$

In which:
DCF: Discounted Cash Flow
t: Applicable Tax
S : Sales Revenue each year
C: Cost each year
D: Depreciation each year (using straight-line method)
PV_n: Present Value at year n
n : Number of year, starts from 0 at the initial year of development
r : Discount Rate (hurdle rate)
NPV: Net Present Value at the end of plant life cycle

RESULT AND DISCUSSION

Driving Forces and Critical Uncertainties Analysis

An outside-in analysis to determine the driving forces of SAF production from available bio-based feedstock in Indonesia is done by viewing internal and external force.s to fuel producing company. This includes gathering data from interview with Government Bodies, Airlines, Fuel Producers, Feedstock Producers, Consultancy bodies, and Experts. The driving forces are mapped as follows:

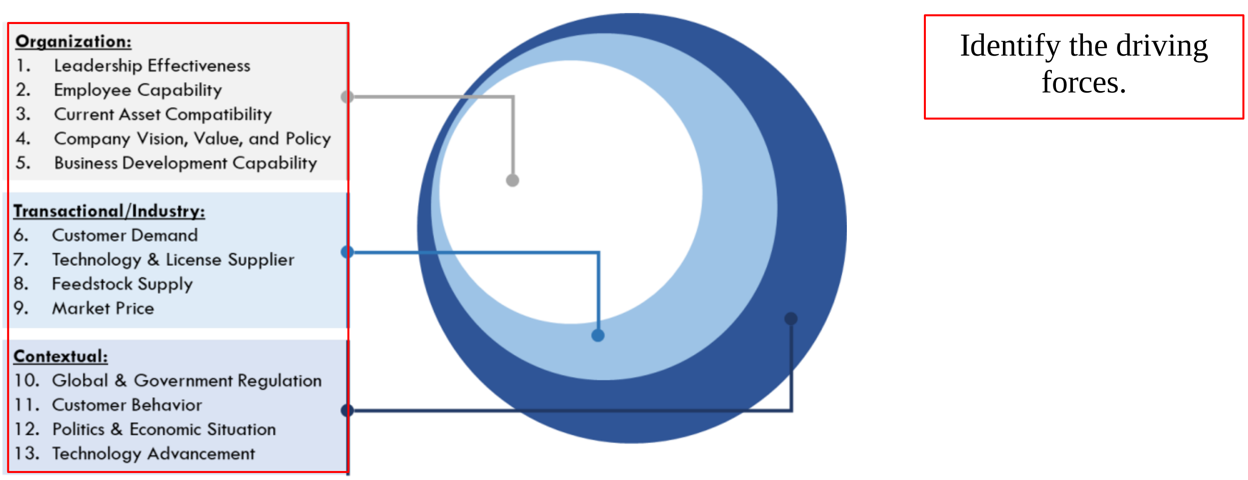
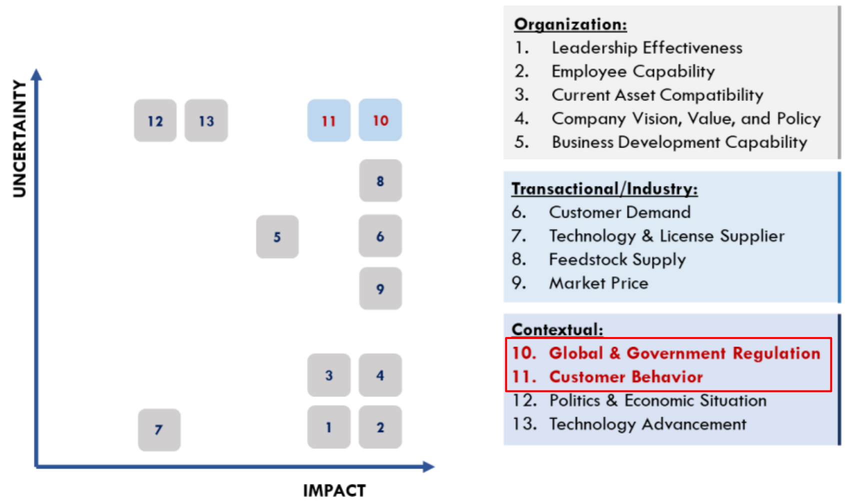


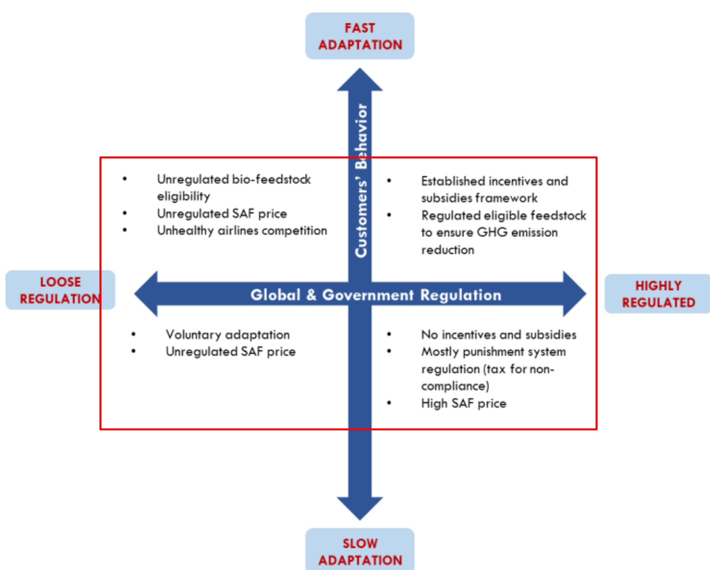
Figure 4. Driving Forces Listing using Outside-in Approach



Determine Critical Uncertainties.

Figure 5. Outside-in Approach in Determining the Driving Forces

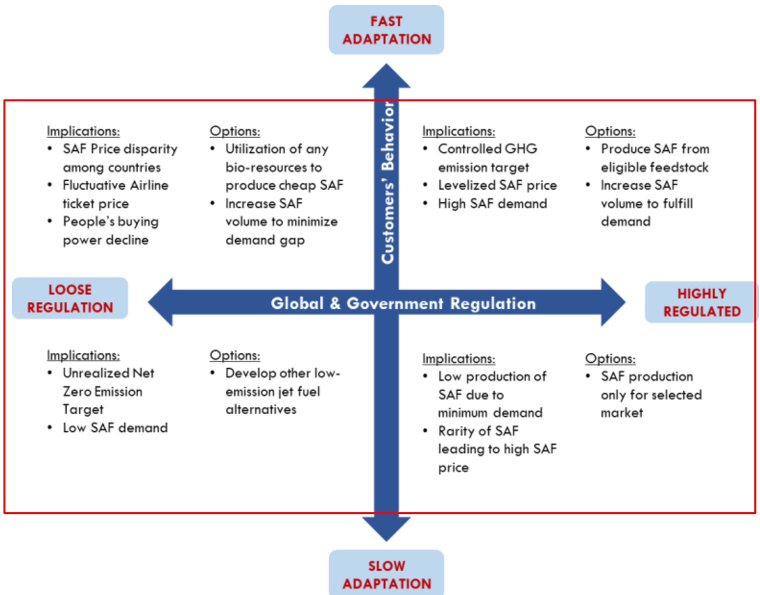
A list of driving forces ranged from internal organization issues to contextual global regulation are listed and grouped with Outside-in Approach framework. From the listed forces, we acknowledge that the contextual forces, namely Global & Government Regulation and Customer Behavior are two factors that have the highest uncertainty since they are beyond company's control while in the same time having the most impact towards company's strategy in developing SAF production. From these two factors, several elements which represent scenarios are listed below:



Develop Scenario Matrix.

Figure 6. Elements of Developed Scenarios

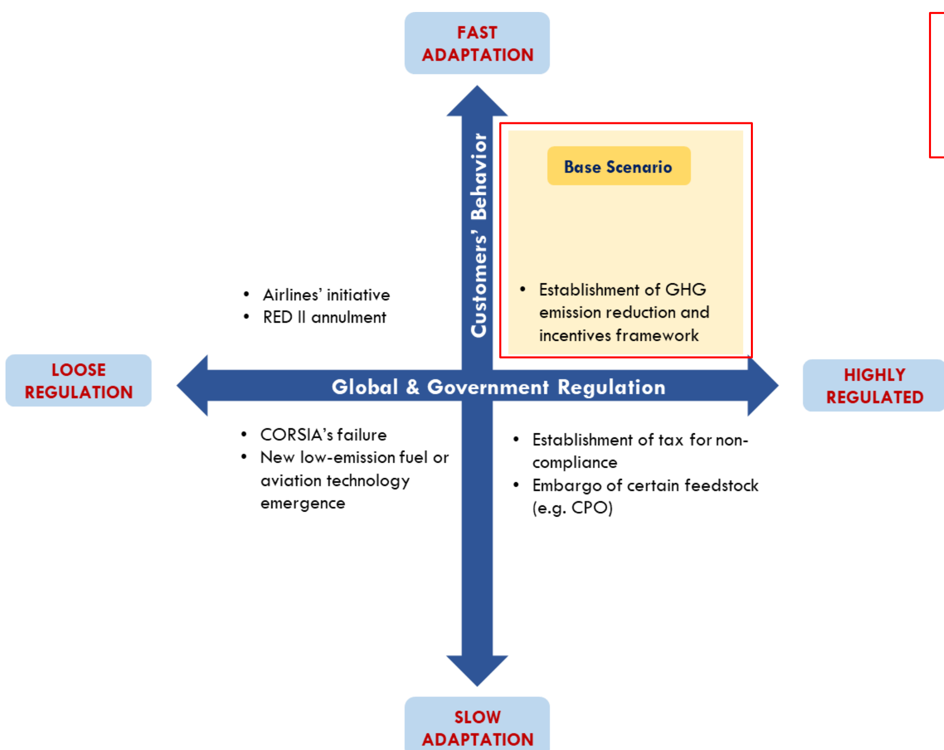
From the elements depicted above, implications and available options for each scenario are listed below:



Develop Implication and Corresponding Option.

Figure 7. Elements of Developed Scenarios

The implications and options are then integrated to determine early warnings for each scenario. This research is then focused on the scenario depicted in the top right quadrant where Global & Government Regulation are established, and the Customers are willing to adopt the SAF due to the established environment.



Identify Early Warning Signal. Use as a Base.

Figure 8. Early Warnings and Base Scenario Definition

The following analysis done for the Business Solution and Implementation Plan are based on the highly regulated and fast adaptation scenario depicted above.

By considering 2 (two) uncertainties factors, one of key success factors of developing SAF product is feedstock selection so that: 1) the feedstock characteristic satisfies the implied regulation thus the SAF product will be acceptable by most of the customers from various countries while 2) the feedstock is sufficiently available to fulfill the growing demand due to the fast adaptation behavior by customer. In this essence, RBDPKO, CPO and UCO are further considered by using AHP method with following parameters:

Table 3. AHP Parameters and Options

Parameter	RBDPKO	CPO	UCO
Availability	Rare (1X)	Abundance (5X)	Challenging (3X)
Price	Low (1X)	Moderate (3X)	High (5X)
CAPEX	Low (1X)	High (7X)	Very High (9X)
Profitability	Low (1X)	High (7X)	Very High (9X)
SAF Marketability	Hard (1/9X)	Moderate (1/3X)	Easy (1X)

From the availability standpoint, CPO is widely available and accessible compared to other feedstocks, hence Fuel Producer can purchase CPO by open tender easily. UCO collection is still a challenge, especially to collect vast amounts of volume to fulfill the Green Refinery production capacity.

Due to its challenging collection process and high demand from foreign countries, UCO price is considerably higher than the others. Due to its high acidity nature, processing UCO needs more pre-treatment than the other feedstocks, hence the higher CAPEX requirements are expected. Due to its popularity in EU countries, SAF produced from UCO has considerably higher price than SAF produced from other feedstocks resulting a higher profitability. UCO-based SAF will definitely be accepted by all airlines while RBDPKO and CPO-based SAF might be subject to anti-dumping policy or even embargo.

The AHP method is then implemented and checked for consistency. All parameters are considered consistent with CR < 0,100. The resulting AHP method is as follows:

Table 4. AHP Result (detailed calculation in Appendix)

Bio Feedstock Option	Multiplier Result
Refined Bleached Deodorized Palm Kernel Oil (RBDPKO)	0,097
Crude Palm Oil (CPO)	0,284
Used Coking Oil (UCO)	**0,619**

From the analysis above, the best strategy option for SAF development is by selecting UCO as the bio-feedstock. The development project essential profile is as follows:

Table 5. The Development Project Essential Profile

Parameter	Estimated Value
Project Cost	~ 700 Mn US$
NPV at Hurdle Rate 9,84%	~ 800 Mn US$
IRR	>20%
SAF Production	~ 240 Thousand KL/year
Main Feedstock	Used Cooking Oil (UCO)

CONCLUSION

Several driving forces that induce SAF production are identified, ranged from Fuel Producer's internal factors to contextual global & Indonesian government's policy. Two factors plays the highest role and considered as the critical uncertainties: Global & Government's Regulation and Customer's Behavior.

From the two critical uncertainties above, a base scenario of "highly regulated and fastly adopted SAF" is selected as the reference of developing the strategy. This scenario is indicated by early warning signs such as: establishment of GHG emission reduction framework, establishment of incentives framework and high SAF demand from airlines.

From the study presented in this paper, the writer recommends to accelerate the SAF development by installing a New Green Refinery with the capability of utilizing Used Coking Oil as a feedstock. Coordinate with Government to develop a robust regulatory framework mandated by the government to support the SAF adoption ranging from the technical specification requirement, trading regulations, up to incentives and/or subsidies essential to help the people afford the increasing fuel price.

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