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Sustainable Competitive Advantage in Indonesia's Bioethanol Industry: Key Variables and Ecosystem Model

Izmirta Rachman[a, b,*]

[a]*Doctoral Student at Prasetiya Mulya University, Jakarta, 12430, Indonesia*
[b]*Chairman of Indonesian Spirit and Ethanol Producers Association (APSENDO), Solo, 57771, Indonesia*

Abstract

The target for bioethanol fuel-grade blending in Indonesia has yet to be achieved, indicating significant barriers to the development of a sustainable industry. This study aims to identify key variables and develop an ecosystem model that supports Sustainable Competitive Advantage (SCA) in the Fuel-Grade Bioethanol Industry (FGBI) in Indonesia. Adopting the Resource-Based View (RBV) and Institutional Theory (IT) approaches, this study analyzes the interaction between internal and external factors influencing industry sustainability. Utilizing an exploratory inductive qualitative method covering the period 2006 to 2024, the research identifies three key RBV variables: (1) demand, (2) raw materials, and (3) technology as well as three coercive IT variables: (1) price formulation, (2) trade structure, and (3) tariffs and incentives as critical elements in achieving SCA. The findings indicate that coercive IT alone is ineffective in achieving SCA without integration with RBV. As both an academic and practical contribution, this study proposes a sustainable ecosystem model for FGBI in Indonesia. Further quantitative testing is needed to examine inter-element dynamics and evaluate the model's long-term effectiveness. The implications for stakeholders highlight the importance of integrating policy with RBV principles to ensure the sustainability of the industry.

Keywords: sustainable competitive advantage; bioethanol industry; key variables; ecosystem model

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1. Introduction[*]

Indonesia's National Energy Policy targets a renewable energy share of at least 23% by 2025 and 31% by 2050 (GoI, 2014), with a bioethanol blending target of 20% in fossil fuel (FO) by 2025 (MEMR, 2015). In comparison, India, through its biofuel blending program, aims to replace 20–30% of FO by 2050 (Gupta et al., 2022). However, electric vehicles remain an unviable solution in Indonesia, as electricity production still heavily depends on fossil fuels (Harinowo & Khaidir, 2024). Indonesia's energy transition faces multiple challenges, including conflicting interests, inconsistent regulations, and low implementation rates, all of which hinder progress (Sekaringtias et al., 2023).

Therefore, further research is needed to explore solutions for overcoming these challenges and ensuring the sustainability of the biofuel economy, particularly in developing countries (Hasan et al., 2023). This study is crucial in supporting national targets for accelerating sugar self-sufficiency and bioethanol production as a biofuel source (GoI, 2023). By 2030, Indonesia aims to produce 1.6 million kiloliters (KL) of bioethanol, with 1.2 million KL allocated for biofuel and 0.4 million KL for other uses (CMEA, 2023).

This study aims to identify key variables and develop an ecosystem model that supports SCA in Indonesia's FGBI. Using RBV and IT approaches, this research analyzes the interactions between internal and external factors that contribute to the industry's sustainability.

RQ1: What are the key variables in RBV and IT that contribute to the creation of SCA in Indonesia's FGBI?
RQ2: Can SCA-FGBI be achieved solely through the independent application of the Coercive IT approach?
RQ3: How do IT and RBV interact in shaping SCA-FGBI at present, and what are the prospects for enhancing the industry's sustainability?

[*] Corresponding author.
E-mail address: izmirtarach@gmail.com

RQ4: What type of ecosystem model can best support sustainability and SCA in Indonesia's FGBI?

This study is expected to contribute to the development of strategic management theory by providing a more precise application and interaction of the RBV, IT, and SCA, particularly in constructing a sustainable fuel-grade bioethanol industry ecosystem model in Indonesia. Furthermore, additional research is needed on the practical application of RBV and its integration with other theories to strengthen strategies for developing the bioethanol industry (Ferreira & Ferreira, 2024). This study holds strategic significance for stakeholders in Indonesia's FGBI sector, enabling them to design RBV- and IT-based policies to establish SCA-FGBI and achieve the objectives outlined in the government's roadmap toward energy self-sufficiency, greenhouse gas reduction, and decreased dependence on fossil fuels.

This study adopts the RBV framework at the national level for FGBI, encompassing various internal strengths while also integrating IT forces, particularly coercive pressures, including government policies from 2006 to 2024. Additionally, this research analyzes the interaction between RBV and IT and their impact on industry sustainability. SCA-FGBI represents a sustainable competitive advantage in Indonesia's FGBI sector, facilitating its growth and independence from the non-energy bioethanol industry. The key parameter for defining SCA-FGBI is the level of program implementation, reflected in the actual bioethanol blending rate adopted by consumers. This study identifies both theoretical and practical gaps in achieving SCA-FGBI. The theoretical gap lies in understanding the interaction between RBV, IT, and SCA, while the practical gap concerns the potential ineffectiveness of coercive policies if not integrated with FGBI's internal strengths within a sustainable ecosystem model.

2. Research Methods

A qualitative approach is employed to gain an in-depth and contextual understanding of key variable identification and the development of an ecosystem model that supports SCA in Indonesia's FGBI. This approach is chosen for its ability to capture the complexity of social dynamics, institutional structures, and resource-related factors, dimensions often inaccessible through purely quantitative or mixed-method approaches, which tend to reduce subjective meanings and contextual nuances. In line with Lim (2024), the qualitative approach is deemed the most appropriate for exploring stakeholder processes and perspectives within complex and dynamic social phenomena.

This study employs an exploratory inductive qualitative approach, conducted in two stages over the 2006–2024 evaluation period. Stage 1 involves a qualitative analysis of primary and secondary data, validated through data triangulation, inter-variable relationship analysis, and practicality testing to ensure its relevance to the bioethanol industry. Stage 2 focuses on in-depth interviews with three fuel-grade bioethanol companies in Indonesia that utilize molasses as a viscous byproduct of sugarcane extraction as a feedstock. The objective is to validate the findings from Stage 1 and to further explore the interrelationships among the identified variables. The selection of these three companies is based on the fact that, at the time of the study, they were the only producers of FGBI using molasses in Indonesia, thereby offering a representative depiction of the entire industry.

Primary data encompasses product samples and Focus Group Discussion (FGD) data, while secondary data includes policy documents, industry data, and official statistics. Validation is performed through source triangulation, cross-referencing with industry associations, and analysis of variable relationships. To ensure the alignment between demand and product quality, samples are analyzed through laboratory testing at an accredited laboratory, utilizing composite sampling techniques from multiple random points in accordance with the Indonesian National Standards (SNI) 7390:2012 and SNI 7390:2022.

In Stage 2, open-ended interviews were conducted in accordance with standard ethical principles, applied both before and during the interviews, focusing on the performance of Indonesia's FGBI from 2006 to 2024. Participants were senior managers with a minimum of 10 years of experience and active membership in the Indonesia Spirits and Ethanol Producer Association (APSENDO). Given the limited number of industry actors, data saturation was achievable with a relatively small sample size within a positivist research framework (Alam, 2021). Triangulation principles were applied to ensure data validity, generalizability, and transparent access to all databases (Tracy, 2019). The research flow is depicted in Figure 1.

Determining sample size to achieve saturation can vary (Hennink & Kaiser, 2022). In this study, saturation was ensured by conducting open-ended, in-depth, and holistic interviews with all fuel-grade bioethanol industry actors utilizing molasses in Indonesia, comprising only three companies, each represented by informants meeting stringent criteria.

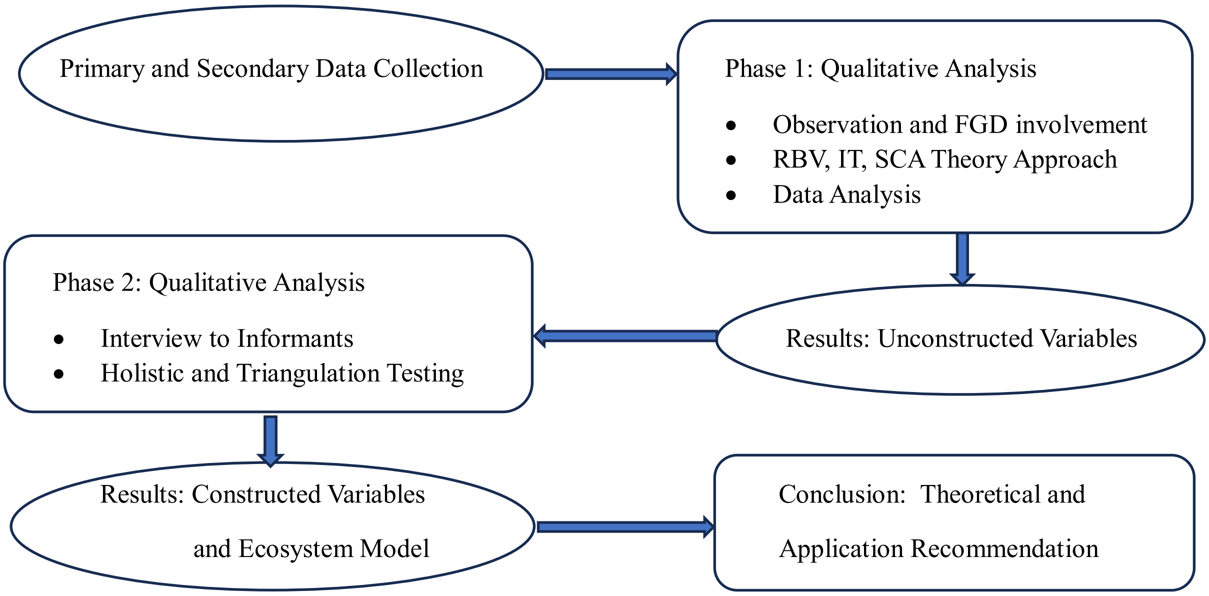


Fig. 1. Research Flow Diagram

Meaning saturation was achieved as all issues were comprehended, and no new information emerged (Rahimi & Khatooni, 2024). All data, including interview transcripts, are publicly accessible. Secondary data validation was performed by obtaining data directly from primary sources and cross-referencing with relevant industry associations.

The research is based on primary and secondary data. Primary data consists of:

a. Direct sampling: to assess the quality of products from producers, bioethanol fuel-grade products are directly sampled from Indonesia's primary bioethanol producers. Laboratory testing is conducted at accredited and competent institutions.

b. FGD reports (2006–2024), covering:

   - The development of bioethanol blending programs
   - Quality assessments and producer readiness
   - Infrastructure preparedness
   - Industrial conditions and sectoral analyzes
   - Relevant regulations
   - Raw material availability

c. Interviews with representatives of all existing bioethanol fuel grade industry players using molasses as a feedstock, currently comprising three companies.

Secondary data consists of:

a. Policy Data:

   - All government policies related to renewable energy, particularly bioethanol, issued between 2006 and 2024.
   - Demand data analyzed from the mandatory program roadmap of the Ministry of Energy and Mineral Resources.

b. Official Industry Data:

   - Installed capacity, raw materials, and technological data obtained from relevant industry associations.

- Production and demand data sourced from industry associations and government institutions.
- Realized distribution data of bioethanol fuel grade from 2006 to 2024.
- Molasses supply data from the Indonesian Sugar Producers Association.

c. Official Statistical Reports:

- Export and import data of molasses (2014–2024).
- Export and import data of ethyl alcohol (2014–2024).
- Market Price Index (MPI) Bioethanol Fuel Grade (2017–2024).
- Mean of Platts Singapore (MOPS) gasoline prices for RON 97, 95, and 92 (2019–2024).
- Import, production, and consumption of gasoline in Indonesia (2011–2023).
- Projected gasoline consumption and bioethanol demand (2024–2030).

3. Results and Discussion

The RBV approach fosters sustainable competitive advantage by leveraging resources that are valuable, rare, inimitable, and non-substitutable (Barney, 1991). It enhances firm performance by identifying and utilizing unique resources and capabilities, generating greater economic value (Barney et al., 2021). The integration of internal resources is crucial for sustaining competitiveness and developing future competitive advantage models (Vigfússon et al., 2025). As RBV continues to evolve with new contexts, concepts, and models (Helfat et al., 2023), future research plays a vital role in providing insights for policymakers to drive innovation in environmentally friendly product design (Khanra et al., 2022).

In the context of IT, institutional pressure has a significant positive correlation with a company's green resources (Huang & Chen, 2023). Compared to normative pressure, coercive and mimetic pressures positively and significantly impact energy management, with coercive pressure exerting a stronger influence than mimetic pressure (Arinaitwe et al., 2024). In Indonesia, the bioethanol industry is still largely dominated by the non-energy sector and export markets. Therefore, stronger government policies are needed to enhance bioethanol utilization in the energy sector, as successfully implemented in the United States and Brazil (Usmani et al., 2023).

The integration of the RBV with the Institutional-Based View (IBV) provides insight into how organizational resources interact with institutional changes, enabling firms to respond effectively. This underscores the importance of combining RBV and IBV to foster competitive advantage and organizational growth (Patnaik et al., 2022). Nandi et al. (2023) applied RBV and IT to examine the sustainability of the biomass-based bioethanol supply chain, confirming its sustainability aspects. However, a conceptual model is still needed to explore the value of resources and capabilities within an ecosystem context, bridging the gap between RBV, IT, and ecosystem literature (Gueler & Schneider, 2021).

Various feedstocks are available for bioethanol production in Indonesia, with selection based on cost, availability, ease of processing, productivity, and non-competition with food supply (Zahroh et al., 2021). Bioethanol technology in Indonesia continues to advance, with research institutions conducting extensive studies and currently testing second-generation bioethanol development at a pilot scale (Sudiyani et al., 2019). However, small-scale trials producing 4 KL per day of fuel-grade bioethanol from sorghum indicate that economic feasibility is achievable only if all unused by-products are converted into high-value products (Wirawan et al., 2024). Globally, the large-scale adoption of second-generation bioethanol technology in the European Union has demonstrated positive environmental impacts, particularly as a replacement for first-generation bioethanol (Wietschel et al., 2021). Meanwhile, research in Malaysia on third-generation bioethanol using *Chlorella vulgaris*, a nutrient-rich unicellular green microalga, indicates that although this technology significantly reduces carbon dioxide emissions, its economic feasibility remains a major challenge (Szulczyk & Tan, 2022).

The first phase of qualitative analysis identified 43 unstructured variables, consisting of 34 RBV variables and 9 IT variables, as shown in Table 1. Subsequently, a second phase of qualitative analysis was conducted through interviews with informants. The results, presented in Table 2, clearly indicate that data saturation was achieved, as evidenced by the repeated occurrence of similar keywords across participants. The importance of demand is highlighted in the statement of Participant 1, a key figure at FGBI Indonesia:

"... the main issue here is demand, Sir. This means ... is that the certainty of contracts still doesn't exist to this day, and we also never know the availability of raw materials. Suddenly, shortages have occurred, and sometimes we have an excess supply and the certainty of prices ..."

Table 1. Unconstructed variable in FGBI Indonesia

Variable	Item
RBV	Molasses Availability, Corn Availability, Cassava Availability, 1st Generation Technology, 2nd Generation Technology, 3rd Generation Technology, Knowledge, Skill, Molasses Price, Demand, Supply, Infrastructure blending, Gas station, People awareness, Quality standard, Product standard, Distribution, Storage tank, Waste management, Financing, Research, Automotive Industry, Academician support, Alliance, Transfer Technology, Flexy vehicle, FGD, Sorghum, Food versus Energy, Deforestation, Media, Productivity industry, Plant area, Raw Material
IT	Formula Price, Government Policy, Tarif and incentive, Trade restriction, Permit and license industry, Energy Policy, Standard quality, Trade structure, Tax and subsidize

Table 2. Summary transcript of all participants in FGBI Indonesia using molasses as raw material

No	Item	Participant 1	Participant 2	Participant 3
1	Participant Position	Manager	Manager	Manager
2	Experience in FGBI	11 years	10 years	20 years
3	Word Count	2667	2032	2700
4	Key Words	Raw materials, Technology, Waste, Demand, Market, Price, Export, Import, Policy	Raw materials, Waste, Purchasing, Absorption, Price, Synchronization, Trade Structure, Incentives	Raw materials, Market, Technology, Vinasse, Synchronization, Price Formulation, Trade Structure, Tariffs and Incentives, Export, Import

The findings derived from interviews, analyzed through triangulation with secondary data on FGBI utilization (Table 3) and further supported by FGD results (Table 6), indicate that the current level of SCA-FGBI remains considerably low. The longitudinal trend over 19 years (2006–2024) demonstrates persistently minimal utilization. Utilization was recorded only during the initial four years (2006–2009), amounting to a total of 4,059 KL. This limited uptake was enabled by a single producer who agreed to supply FGBI at a price of MOPS plus IDR 1,000. However, this arrangement was discontinued in 2010 due to the rising cost of molasses, which rendered the selling price commercially unfeasible. Over the 19 years, the average annual purchase volume was merely 267.1 KL, with no recorded transactions in nine of those years—specifically in 2010, 2011, 2013, and from 2017 to 2022. Since the introduction of Pertamax Green 95 (E5 type, a fuel blend containing 5% ethanol and 95% gasoline by volume) in 2023, market activity has shown a slight improvement, although it remains limited. In 2024, consumer purchase utilization reached only 373.1 KL, representing approximately 0.59% of Indonesia’s installed FGBI production capacity (Table 5).

Table 3. Utilization of FGBI Indonesia

Year	2006	2007	2008	2009	2010-2011	2012	2013	2014	2015	2016	2017-2022	2023	2024
Utilization (KL)	100.4	448.0	1,673.0	1,838.0	0	8,2	0	25.0	498.4	8.0	0	104.0	373,1

Source: APSENDO, processed by the researcher

Table 4. Primary RBV and IT variables in FGBI Indonesia

Approach	Variable	Explanation
RBV	1. Demand	Demand from FO Enterprises
	2. Raw Material	Availability of competitively priced raw materials
	3. Technology	First-generation technology with proper waste management support
IT	1. Price Formula	Improvement of bioethanol MPI policies
	2. Trade Structure	Restriction on raw material exports

Approach	Variable	Explanation
	3. Tariff and Incentive	Development of tariff and incentive

Table 5. Installed capacity, raw materials, and technology options for the bioethanol industry in Indonesia

No	Company Name	Capacity (Liter/Year)	Raw Material	Technology	Fuel Grade Capacity (Liter/Year)
1	PT. Energi Agro Nusantara	30.000.000	Molasses	First Generation	30.000.000
2	PT. Molindo Raya Industrial	80.000.000	Molasses	First Generation	10.000.000
3	PTPN XI-Djatiroto	2.025.000	Molasses	First Generation	-
4	PT. Madubaru	7.500.000	Molasses	First Generation	3.000.000
5	PT. Indo Acidatama Tbk	58.825.000	Molasses	First Generation	-
6	PT. Indonesia Ethanol Industry	62.000.000	Corn	First Generation	20.000.000
7	PT. PG Rajawali II Unit PSA Palimanan	3.000.000	Molasses	First Generation	-
8	PT. Etanol Ceria Abadi	13.200.000	Molasses	First Generation	-
9	PT. Molasindo Alur Pratama	3.600.000	Molasses	First Generation	-
10	PT. Basis Indah	3.000.000	Molasses	First Generation	-
11	PT. Indolampung Distellary	50.000.000	Molasses	First Generation	-
12	PT. Medco Ethanol Lampung	50.000.000	Cassava and Molasses	First Generation	-
13	PT. Semarang Herbal Indoplant	2.000.000	Molasses	First Generation	-
	Total	365.150.000			63.000.000

Source: APSENDO, processed by the researcher

The total installed capacity of Indonesia's bioethanol industry (energy and non-energy) in 2023 was 365.15 thousand KL per year. Meanwhile, Indonesia's FGBI installed capacity was 63 thousand KL per year, accounting for 17.25% of the national bioethanol industry capacity, with four out of thirteen industry players ready to produce bioethanol fuel grade: PT. Energi Agro Nusantara, PT. Molindo Raya Industrial, PT. Madubaru, and PT. Indonesia Ethanol Industry (IEI), with installed capacity provided respectively at 30,000 KL, 10,000 KL, 3,000 KL, and 20,000 KL per year. IEI was excluded from the interview sample as it is a new plant that began production in 2023 and uses corn as raw material.

RQ1 = What are the key variables in RBV and IT that contribute to the creation of SCA in Indonesia's FGBI?

Table 4 presents three main structured RBV variables and three structured IT variables derived from in-depth, open-ended interviews with all participants, following the application of triangulation with supporting data.

3.1. Demand

According to the VRIN framework proposed by Barney in 1991, demand constitutes a valuable resource, particularly when manifested in the form of consumer purchase contracts. Although Table 7 indicates a high level of potential demand, this is not reflected in actual utilization, as shown in Table 3. Gasoline consumption has increased over the past 13 years, from 26.45 million KL in 2011 to 36.02 million KL in 2023. With mandatory programs under regulations (MEMR, 2015) (MEMR, 2008), potential demand should have increased from 1.85 million KL in 2011 to 3.60 million KL in 2023.

In 2024, the government is conducting a study to reduce the blending target to 5% in 2025 and 10% in 2030, prioritizing general fuel as gasoline for the non-public service obligation (non-PSO) program. As a result, the potential demand until 2030 can be seen in Table 8. The demand in 2025 is estimated at 394,288 KL and is expected to grow continuously, reaching 1,055,205 KL by 2030.

3.2. Raw Material

The second variable is the primary raw material, molasses, where Indonesia is in a surplus position. The average supply of molasses from sugar mills over the last 15 years (2010 to 2024) has been 1.523.768 tons. However, despite the surplus in industry data, producers face difficulties in obtaining raw materials upon confronting interview data and statistics. Based on the data from the last eleven years (2014 – 2024), Indonesia has consistently been a net exporter of molasses, with the highest value in 2014 at 938,284 tons and the lowest in 2017 at 399,700 tons. Indonesia (Table 10). exports molasses extensively to Asian countries such as the Philippines, Thailand, Korea, and Japan and in smaller quantities to various other countries, including the Netherlands, Australia, New Zealand, UAE, and even Russia

3.3. Technology

The third variable is first-generation technology with appropriate waste management support. All bioethanol plants in Indonesia using molasses as raw material are required to address vinasse waste management issues. Vinasse is a liquid byproduct generated from the ethanol distillation process. Managing vinasse is crucial because it can be hazardous as a pollutant if released into the environment untreated. Vinasse is rich in minerals and potential nutrients for organic fertilizers. Commercial technologies are available to convert vinasse into biogas, which can then be used to generate electricity as renewable energy (Balakrishnan, 2024). Here is the related statement from Participant 2:

"... the issue of waste management or vinasse, which is relatively large, about ten to twelve times the amount of ethanol produced. However, the capacity or absorption capacity for treating this waste is minimal..."

With the threat of food supply disruption and the need to support food self-sufficiency programs, especially for sugar (GoI, 2023), Indonesia should not rely solely on first-generation technology. The best solution to reduce investment costs and food risks is integrating second-generation bioethanol technology into existing first-generation facilities rather than building standalone second-generation facilities (Lennartsson et al., 2014). Integration strategies can be implemented through three alternatives: (1) Via colocation, integrating second-generation technology into existing first-generation facilities; (2) Retrofitting, adapting on the same production line; or (3) Repurposing, adapting processes to existing technology (Guimarães et al., 2023). Table 11 presents the results of sample product analysis conducted in an accredited laboratory, demonstrating that the products have met domestic standard specifications in terms of quality. Domestic FGBI products meet the domestic market's standards and quality of fuel as stipulated by government regulations (MEMR, 2023a).

Table 6. Summary Chronology of FGD

Year	Summary
2006	Pertamina voluntarily markets biopremium (RON 88) and biopertamax (RON 92) with 3.5-5% bioethanol content. Implementation is limited to major cities such as Malang, Surabaya, Jakarta, and Denpasar. Over four years, a total of 4,059.4 KL has been realized. The pricing agreement is based on gasoline prices (MOPS) + IDR 1,000.
2008	Regulations on Biofuel's provision, utilization, and trade structure were issued (MEMR, 2008). The bioethanol industry began to emerge, and new business licenses for bioethanol commerce started to be issued. Pertamina's distribution of bioethanol stopped due to economic feasibility issues arising from the increase in molasses raw material prices.
2010	Pertamina's distribution of bioethanol stopped due to economic feasibility issues arising from the increase in molasses raw material prices.
2014	The regulation on MPI bioethanol was issued (MEMR, 2014a) based on Argus Thailand prices. Pertamina Surabaya conducted small-scale purchases for testing purposes, amounting to 25 KL. PT. Energi Agro Nusantara, as a supplier, made its inaugural export sale of 3,725 KL to the Philippines.
2015	PT. Shell Indonesia blended E2 with RON 92 and RON 95, but the practice did not last long and ceased in the same year due to technical infrastructure considerations.
2016	New regulations on MPI bioethanol were issued (MEMR, 2016) based on domestic molasses prices. Pertamina started blending bioethanol for Pertamax Racing products.
2017-2022	During the period without utilization, various FGDs were discussed: 1. Infrastructure readiness in terms of facilities and infrastructure. 2. Bioethanol prices that have not reached economic viability. 3. Technical procurement from state-owned and private enterprises. 4. Plans for implementing the E2 program in East Java, considering the location of producers. 5. Business processes are handed over on a business-to-business basis.
2023	The inaugural launch of Pertamax Green 95, which is a blend of 5% bioethanol with RON 92 gasoline.
2024	Discussion regarding the proposed changes to the blending target to 5% in 2025 and 10% in 2029 specifically for non-public service obligation, the addition of a price formula based on agreements for the voluntary program, and the implementation of an import policy if local producers' utilization has reached its maximum capacity.

Table 7. Gasoline supply and demand in million KL, target and program realization (2011 - 2023)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Import	15,76	18,39	19,68	20,60	19,60	16,84	18,37	18,70	19,31	17,44	18,70	21,91	21,21
Production	10,75	11,24	11,29	11,92	12,89	14,93	14,85	14,94	15,39	14,59	14,83	13,86	14,24
Consumption	26,45	29,28	30,51	30,92	31,53	32,63	33,55	34,49	35,68	31,19	32,95	35,80	36,02
Mandatory	7%	7%	7%	7%	2%	5%	5%	5%	5%	10%	10%	10%	10%
Target (million KL)	1,85	2,05	2,14	2,16	0,63	1,63	1,68	1,72	1,78	3,12	3,30	3,58	3,60
Realization (KL)	-	8,2	-	25	498	8	-	-	-	-	-	-	104
Realization/Target	0	0,0004%	0	0,001%	0,08%	0,0005%	0	0	0	0	0	0	0,003%

Source: FGD-MEMR, processed by the researcher

Table 8. Consumer demand potential gasoline for the proposed mandatory program (2024 - 2030)

Description/Year	2024	2025	2026	2027	2028	2029	2030
Projected Consumption (KL)	39.428.776	41.336.620	43.403.451	45.629.269	47.855.087	50.247.841	52.760.233
PSO Gasoline (KL)	31.543.021	33.069.296	34.722.761	36.503.415	38.284.070	40.198.273	42.208.187
Non-PSO Gasoline (KL)	7.885.755	8.267.324	8.680.690	9.125.854	9.571.017	10.049.568	10.552.047
Proposed Roadmap (%)	5%	5%	5%	5%	5%	10%	10%
Bioethanol Demand (KL)	394.288	413.366	434.035	456.293	478.551	1.004.957	1.055.205

Source: FGD-MEMR, processed by the researcher

Table 9. Molasses production from 2010 to 2024

Year	Areal (000 ha)	Cane (ton)	Sugar (ton)	Molasses (ton)	Molasses/Cane (%)
2010	432.737	35.458.022	2.290.130	1.597.176	4,50
2011	432.830	28.856.722	2.135.825	1.370.014	4,75
2012	442.477	31.888.930	2.591.687	1.570.012	4,92
2013	469.227	35.526.071	2.551.023	1.571.424	4,42
2014	472.676	33.686.802	2.575.392	1.678.016	4,98
2015	446.043	30.165.767	2.498.086	1.443.182	4,78
2016	437.356	33.369.842	2.204.299	1.621.212	4,86
2017	427.360	28.733.678	2.118.929	1.417.112.	4,93
2018	414.136	28.030.875	2.172.385	1.250.924	4,46
2019	411.435	27.728.271	2.227.047	1.412.221	5,09
2020	420.505	29.737.781	2.130.719	1.471.030	4,95
2021	450.619	32.153.388	2.330.777	1.510.682	4,70
2022	485,824	36.180.993	2.386.291	1.621.543	4,48
2023	509.508	37.463.341	2.740.730	1.685.850	4,50
2024	520,823	33.216.612	2.465.739	1.636.127	4,93

Source: Indonesian Sugar Association data, processed by the researcher

Table 10. Indonesia's molasses export-import (HS Code: 17031090) in Ton

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Export	938.284	420.615	439.107	412.204	502.764	640.771	428.756	570.797	604.376	819.581	494.122
Import	0	12.264	2	12.505	12	17	156	3.220	20.548	16.067	1.643
Net	938.284	408.352	439.105	399.700	502.751	640.755	428.600	567.577	583.828	803.514	492.479

Source: Central Bureau of Statistics (BPS), processed by the researcher

3.4. Price Formula

The government has gradually adjusted the bioethanol price over a certain period (GoI, 2006a). Concrete pricing policies began in 2014, referencing the Argus publication price for FOB Thailand Ethanol, averaged over the previous month, plus 14% (MEMR, 2014a). This policy was deemed unsuitable given that the bioethanol used local raw materials. This policy was revoked in 2016, changing to The Kharisma Pemasaran Bersama Nusantara (KPBN) publication price for molasses, averaged over the last three months of publication, excluding value-added tax, with a conversion factor of 4.125 kg of molasses per liter of ethanol, plus a molasses-to-ethanol conversion rate of 0.25 USD per liter (MEMR, 2016). According to (Pebdani et al., 2022), price and tariff decisions play a crucial role in the profitability of suppliers and the success of meeting demand for industry sustainability. Table 12 presents detailed monthly data on the bioethanol MPI over eight years, from 2017 to 2024, with an average value of IDR 11,964 during that time.

Only two factors can influence the government's formula: the average auction price of molasses over three months at KPBN and the exchange rate conversion factor from USD to IDR. The high auction price of molasses is the leading cause of the MPI Bioethanol. The author also compared the last six years (2019 - 2024), showing that the MPI Bioethanol has consistently exceeded the MOPS Gasoline. Figure 2 illustrates this relationship through a comparative graph depicting the Bioethanol MPI alongside MOPS Gasoline. According to Dessi et al. (2022); biofuel prices for consumers will be more expensive than fuel oil (FO) in the short term, at least during the market introduction period, and this price gap will decrease in the long term.

3.5. Trade Structure

Table 10 illustrates Indonesia's position as a net exporter of molasses, supported by interview findings that the trade management of raw materials is essential for FGBI Indonesia. Raw materials available at competitive prices will reduce production costs, lowering bioethanol's selling price. Consequently, the business-to-business concept can be achieved if the MPI Bioethanol falls below the MPI FO.

Table 13 demonstrates that Indonesia has maintained its status as a net exporter of ethanol over the past eleven years. The net export values for Indonesia in 2023 and 2024 were 42.647 tons and 29.261 tons, respectively. There is no reason to import fuel-grade bioethanol for the short term as long as domestic production utilization remains very low. However, the threat of future imports should be considered in line with the rising potential demand according to the roadmap (MEMR, 2015).

Table 11. Results of quality testing of bioethanol fuel grade at the Balai Besar Pengujian Minyak dan Gas Bumi, Lemigas, Indonesia, in June 2023.

No	Parameter	Unit	Sample Result	SNI 7390:2012	SNI 7390:2022
1	Ethanol Content	% vol, min	99,82 (after *denatonium benzoate* denaturation)	99,5 (after *denatonium benzoat* denaturation) 94,0 (after *hydrocarbon* denaturation)	99,2 (after *denatonium benzoat* denaturation) 94,0 (after *hydrocarbon* denaturation)
2	Methanol Content	% vol, max	<0.001	0.5	0.5
3	Water Content	% vol, max	0.12	0.7	0.3
4	Denaturant Content hydrocarbon, or	% vol	-	2 - 5	2 - 5
	Denatonium benzoat	mg/liter	5	4 - 10	4 - 10
5	Copper Content (Cu)	mg/kg, max	<0.01	0.1	0.1
6	Acidity as Acetic Acid	mg/liter, max	17.5	30	56
7	Appearance	Visual	Clear and Bright, Free sediment & impurities	Clear and Bright, Free sediment & impurities	Clear and Bright, Free sediment & impurities
8	Chloride ion content	mg/liter, max	<0.1	20	20
9	Sulfur Content (S)	mg/liter, max	2.1	50	50
10	Washed Gum	mg/100 ml, max	<0.5	5.0	5.0

Table 12. Government-set MPI bioethanol fuel grade data for the period 2017-2024

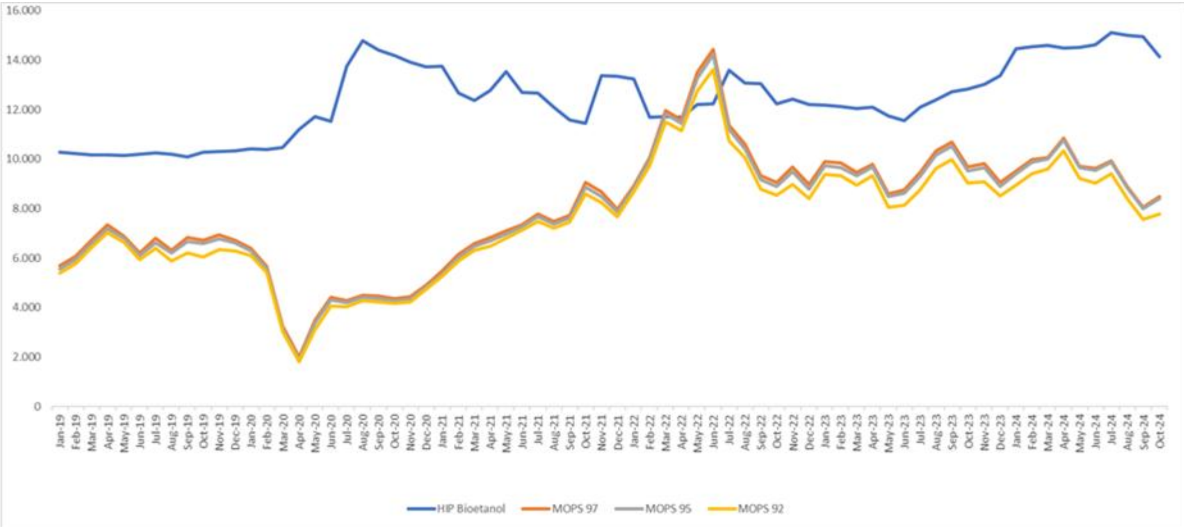
Year/Month	January	February	March	April	May	June	July	August	September	October	November	December	Average	
2017	Rp11.049	Rp11.036	Rp11.026	Rp11.028	Rp11.018	Rp11.020	Rp10.874	Rp10.885	Rp10.475	Rp10.168	Rp10.074	Rp10.088	Rp	10.728
2018	Rp10.090	Rp10.059	Rp10.083	Rp10.140	Rp10.147	Rp10.210	Rp 9.900	Rp10.010	Rp10.337	Rp10.337	Rp10.457	Rp10.362	Rp	10.178
2019	Rp10.274	Rp10.235	Rp10.167	Rp10.178	Rp10.195	Rp10.201	Rp10.255	Rp10.200	Rp10.091	Rp10.273	Rp10.297	Rp10.348	Rp	10.226
2020	Rp10.424	Rp10.384	Rp10.461	Rp11.210	Rp11.709	Rp11.516	Rp13.759	Rp14.779	Rp14.418	Rp14.178	Rp13.919	Rp13.720	Rp	12.540
2021	Rp13.748	Rp12.659	Rp12.367	Rp12.786	Rp13.531	Rp12.709	Rp12.673	Rp12.113	Rp11.571	Rp11.447	Rp13.379	Rp13.361	Rp	12.695
2022	Rp13.237	Rp11.695	Rp11.708	Rp11.704	Rp12.214	Rp12.236	Rp13.602	Rp13.068	Rp13.045	Rp12.234	Rp12.430	Rp12.205	Rp	12.448
2023	Rp12.186	Rp12.180	Rp12.041	Rp12.107	Rp11.742	Rp11.558	Rp12.112	Rp12.390	Rp12.725	Rp12.825	Rp13.018	Rp13.370	Rp	12.355
2024	Rp14.741	Rp14.539	Rp14.587	Rp14.496	Rp14.528	Rp14.622	Rp15.101	Rp15.010	Rp14.938	Rp14.144	Rp14.039	Rp13.725	Rp	14.539
											8 Years Average		Rp	11.964

Source: MEMR publications and processed by researcher

3.6. Tariff and Incentive

Export-import tariff policies must be managed for molasses raw materials and bioethanol products. It is time to implement export duties on molasses or even prohibit the export of molasses. Incentives should also be provided, especially for producers or consumers who utilize bioethanol until economic viability is achieved.

The potential supply of imported bioethanol products mainly comes from Pakistan, Brazil, and the USA. Pakistan poses the greatest threat that could disrupt Indonesia's domestic bioethanol market. The imbalance in import duty tariffs with Pakistan is the trigger. Specifically, the import duty tariff from Pakistan has been 0% since 2019 based on the Indonesia-Pakistan Preferential Trade Agreement (IP-PTA) (GoI, 2018; MoF, 2019). Conversely, the import duty in Pakistan with the same HS Code 2207 is 50% and 90%. Table 14 shows the increase in bioethanol imports, especially from Pakistan, since 2019. The general import duty tariff is 30% for ethanol and applies to almost all countries. The Indonesian government also permits a 0% ethanol import tariff for ASEAN member countries under the ASEAN Trade in Goods Agreement (ATIGA) (MoF, 2022), but it applies reciprocally.



Source: FGD-MEMR and processed by researcher

Fig. 2. Comparison graph of MPI bioethanol with MOPS gasoline RON 97, 95, and 92 in IDR per Liter

Table 13. Export-import *Ethyl-alcohol* Indonesia in Ton

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Export	73.863	52.437	55.843	50.463	124.699	54.788	36.563	64.449	60.883	47.056	39.745
Import	1.291	135	1.771	3.835	75.855	513	22.520	42.514	25.617	4.409	10.484
Net Exporter	72.572	52.302	54.072	46.628	48.844	54.275	14.043	21.935	35.266	42.647	29.261

Source: BPS and processed by researchers

Table 14. Import *ethyl-alcohol* nationally and specifically from Pakistan in Ton

Import	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
National (N)	1.291	135	1.771	3.835	75.855	513	22.520	42.514	25.617	4.409	10.484
Pakistan (P)	29	17	19	1.200	-	388	19.750	37.864	24.325	4.163	10.155
P/N (%)	2,26	12,95	1,09	31,28	-	75,62	87,70	89,06	94,96	94,41	96,86

Source: BPS and processed by researcher

3.7. IT-Coercive Approach

RQ2 = Can SCA-FGBI be achieved solely through the independent application of the Coercive IT approach?

The Indonesian government carried out the policy selection process across various energy regulations from 2006 to 2024. Table 15 outlines eighteen policies directly related to renewable energy, with a particular focus on bioethanol. Based on interviews with all participants and triangulation techniques involving utilization data and achievements of SCA-FGBI, all these policies are deemed neutral and have not convincingly facilitated SCA-FGBI participants. However, participants are optimistic about future improvements, such as enhancements in pricing formulas, trade management, tariffs, and incentives. Statement from Participant 3, a pioneer of FGBI Indonesia:

"... because various regulations consistently issued by the government discuss it yearly. The reality is, however, that for the industry itself, these regulations do not directly correlate with the business ..."

The establishment of strong and coherent policy support in Indonesia, particularly when integrated with RBV framework, is critically important. Empirical evidence indicates that countries with well-developed and integrated policy environments, such as the United States and Brazil, demonstrate superior performance in the biofuel sector. In contrast, countries with less comprehensive policy support, such as Japan and Malaysia, tend to lag in terms of sectoral development and competitiveness (Usmani et al., 2023). New and renewable energy resources are regulated by the state and utilized for the prosperity of the people (GoI, 2007). National energy policies are based on principles of justice, sustainability, and environmental awareness principles to achieve energy self-sufficiency and national energy security (GoI, 2017). The potential demand begins with the national policy target of achieving a 5% biofuel blending target by 2025 (GoI, 2006a). This target was gradually achieved, starting from 1% in 2009 and increasing to 15% by 2025 (MEMR, 2008). The emphasis on blending obligations, administrative sanctions, and the change in blending targets to 20% by 2025 saw regulatory changes three times per year (MEMR, 2013; MEMR, 2014b; MEMR, 2015) reflecting a lack of planning and coordination among stakeholders in the industry. (Khatiwada & Silveira, 2017) projected Indonesia to achieve an E10 blending target by 2020 with bioethanol production of 4.45 million liters, supported by achieving sugar self-sufficiency through expanding sugarcane plantation areas to 1.6 million hectares. However, these potential figures have substantially fallen short, as illustrated in Table 9.

RQ3 = How do IT and RBV interact in shaping SCA-FGBI at present, and what are the prospects for enhancing the industry's sustainability?

Based on qualitative analysis, neither IT nor RBV alone is sufficient to achieve SCA-FGBI in Indonesia; however, their integration is expected to facilitate its attainment in Indonesia. Data analysis from 2006 to 2024 indicates that coercive IT policies implemented without considering the industry's internal RBV conditions do not exhibit a positive correlation with SCA-FGBI. In contrast, when IT is strategically developed and aligned with internal resources that are valuable, rare, inimitable, and well-organized, SCA-FGBI can be achieved more effectively. Therefore, a holistic approach integrating technological advancements with internal resource management is essential for building sustainable competitiveness.

Future prospects indicate that the integration of IT and RBV has received a positive response from industry stakeholders, with increased investment in technologies that enhance production efficiency and sustainability, combined with the optimization of internal industry capabilities, serving as key factors in strengthening SCA-FGBI. Therefore, further qualitative and quantitative research is needed to explore the dynamics of the IT-RBV relationship and assess its long-term effectiveness.

The theoretical implications suggest that integrating IT expansion into RBV within the FGBI context can enhance SCA by creating a resource-based advantage reinforced by technology. For practitioners, it is essential to ensure that IT policies are not merely regulatory but also contribute to strengthening RBV to generate a positive impact on SCA. However, this study's exploratory and inductive nature presents a key limitation, necessitating a more comprehensive research approach that incorporates an exploratory sequential method and quantitative testing to validate these findings. Furthermore, as the study's participant representation is limited to Indonesia's FGBI, future research should encompass the broader non-energy bioethanol industry and other key stakeholders to provide a more comprehensive understanding.

3.8. Ecosystem Model

RQ4 = What type of ecosystem model can best support sustainability and SCA in Indonesia's FGBI?

Ecosystems emphasize interaction, feedback, and interdependence among elements (Geary et al., 2020). They must be flexible and responsive to change, incorporating new information and stakeholder input to address uncertainty and evolving conditions (DeFries and Nagendra, 2017). Maintaining ecosystem health and resilience is essential and requires integrating ecological principles into policy and management frameworks (Sarda et al., 2014). Ecosystems function as interconnected organizations supported by modularity rather than hierarchical management. They coordinate multilateral dependencies through a set of roles while adhering to common rules (Jacobides et al., 2018). A conceptual model of resource values is still needed to bridge the gap between resource perspectives, institutional theory, and ecosystem literature (Gueler and Schneider, 2021).

Empirical data and qualitative analysis indicate that each variable interacts dynamically with others. For example, during the period from 2006 to 2009, a reduction in producer prices led to a significant increase in demand. In contrast, the scarcity of molasses as a raw material, resulting from increased exports between 2010 and 2024, contributed to a slowdown in demand growth. The implementation of the E5 policy, together with the Pertamax Green program in 2023, began to stimulate demand in both 2023 and 2024. However, the impact has remained limited due to the imposition of excise duties on the product. These dynamics underscore the need for more rigorous quantitative research to develop constructive propositions regarding the interrelationships among these elements and to gain a deeper understanding of the correlations and interactions among variables within the broader context of sustainability.

The FGBI ecosystem model, derived from a quantitative study involving an analysis of variable relationships, practicality testing, and triangulation analysis based on interviews, is presented in Figure 3. Each element interacts and depends on others within a mutually beneficial environment.

Table 15. Indonesia bioethanol program and energy policy (2006 – 2024)

No	Issued Date	Citation	Topic
1	25 January 2006	(GoI, 2006a)	Provision and Utilization of Biofuels as Alternative Fuels
2	25 January 2006	(GoI, 2006b)	National Energi Policy
3	10 Oktober 2006	(MEMR, 2006)	Requirements and Guidelines for Licensing Biofuels as Alternative Energy Sources
4	10 Agustus 2007	(GoI, 2007)	Energy
5	26 September 2008	(MEMR, 2008)	Provision, Utilization, and Trade of Biofuels as Alternative Fuels
6	28 Agustus 2013	(MEMR, 2013)	Amendment to MEMR (2008) Regulations
7	03 July 2014	(MEMR, 2014b)	Second Amendment to MEMR (2008) Regulations
8	02 Oktober 2014	(MEMR, 2014a)	MPI Biofuels Blended into Specific Types of FO
9	17 Oktober 2014	(GoI, 2014)	National Energy Policy
10	18 Maret 2015	(MEMR, 2015)	Third Amendment to MEMR (2008) Regulations
11	01 July 2016	(MEMR, 2016)	MPI Biofuels Blended into FO
12	02 Maret 2017	(GoI, 2017)	National General Energy Plan
13	01 April 2021	(MEMR, 2021)	Business Activity and Product Standards in Energy and Mineral Resources Sector Licensing Based on Risk
14	16 Juni 2023	(GoI, 2023)	Accelerating Sugar Self-Sufficiency and Provision of Bioethanol as Biofuels
15	19 Juni 2023	(MEMR, 2023a)	Standards and Quality of Bioethanol Type Biofuels Marketed Domestically
16	13 July 2023	(MEMR, 2023b)	Standards and Quality of FO Type Gasoline RON 95 with 5% Bioethanol Blend Marketed Domestically
17	15 December 2023	(CMEA, 2023)	Road Map for Accelerating National Sugar Self-sufficiency and Providing Bioethanol as a Biofuel for 2024-2030
18	19 April 2024	(GoI, 2024)	Establishment of a task force to accelerate sugar and bioethanol self-sufficiency in Merauke district, South Papua

The ecosystem model can serve as a foundation for the development of FGBI in Indonesia and other developing countries. This model also provides a basis for further research; however, quantitative testing is necessary to explore the dynamics of relationships among elements and evaluate the model’s long-term effectiveness for industry sustainability. By leveraging the synergy between IT and RBV, FGBI is expected to develop sustainably and become increasingly competitive at the global level.

4. Conclusion

Through qualitative study and RBV theory approach, three main variables causing the inefficiency of SCA-IBFG Indonesia were identified: (1) Demand, (2) Raw Materials, and (3) Technology. Furthermore, using an IT approach, three main variables causing the lack of SCA-FGBI Indonesia were identified: (1) Price Formulation, (2) Trade Structure, and (3) Tariffs and Incentives. The application of coercive IT alone proved ineffective in achieving SCA-FGBI Indonesia. Furthermore, the integration of IT and RBV is essential. Based on qualitative testing, unintegrated IT and RBV cannot effectively facilitate the smooth implementation of SCA. The ecosystem model developed in this study offers a conceptual framework for ensuring the sustainability of FGBI in Indonesia.

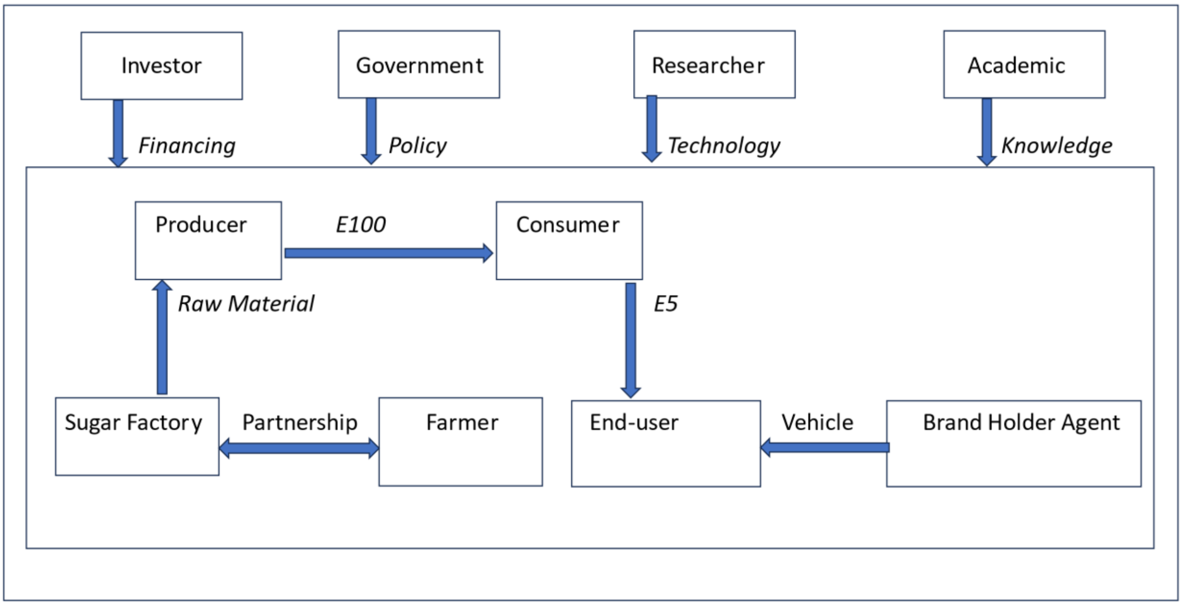


Fig. 3. Ecosystem Model for FGBI in Indonesia

The practical implications for stakeholders highlight the need to optimize key variables through the integration of IT and the RBV. Achieving sustainability requires that industry actors and policymakers do not operate in isolation. Instead, cross-sector collaboration based on an ecosystem model is essential, as it fosters mutually beneficial interactions among stakeholders. Therefore, fragmented, sector-specific approaches must be replaced with holistic, adaptive, and collaborative strategies oriented toward shared objectives. The future development of this ecosystem model involves analyzing the role of each element and requires further qualitative or quantitative testing to refine and validate the interactions among these elements.

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