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Technology Policy Assessment of Methane Capture Development in Palm Oil Biodiesel Chain Production

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Abstract

Technology implementation contributed significantly in Greenhouse Gas (GHG) emission reduction from biodiesel production chain. Methane capture is biggest contributor for GHG emission reduction among several identified technologies in palm oil biodiesel production. Aim of the paper was to assess technology policy for methane capture technology development in reduction GHG emission. Technology policy assessment was conducted by employing technology management approach. Initially, Technology strategy was formulated by analysis of technology status, technology capabilities and technology climate for methane capture implementation. Non Numeric Multi-Experts Multi Criteria Decision Model (ME-MCDM) was employed to assess technology status, capabilities, and climate, while technology strategy was determined by developing of If-Then Rule. Analysis result of technology policy for methane capture technology show level of technology status, technology capabilities and technology climate were medium, therefore strategic alliance in technology development was recommended as technology acquisition strategy.

Keywords: Technology Policy, GHG emission, Biodiesel Industry

1. Introduction

Recently, GHG emission reduction from production chain of palm oil biodiesel should meet minimum reduction requirement which have been issued by some imported countries. US have been lauched a standard of GHG reduction minimum by 20 %, while European Union by 35 %. Also, Government of Indonesia committed in GHG emission reduction by 26 % with national effort and by 41 % with international support in 2020. Technology implementation contribute significantly in GHG emission reduction. Study on GHG emission scenario in Asia until 2050, show implementation key technologies could reduce potentially by 60 % (Akashi, Hijioka et al. 2012). Also, as illustration, Carbon Capture and Storage (CCS) implementation could reduce carbon emission by 90 % at power generation (Pacala and Socolow 2004). Therefore, global sharing on technology innovation will reduce GHG emission significantly (Smith, Howden et al. 2007).

In encouraging the role of technology, technology policy assessment should be conducted. Technology policy is defined as generation, acquisition, adaptation, diffusion and use of technological knowledge in a way that the government deems useful for the society rather than individuals (Chang 2002). In reduction of GHG emission term, technology policy was focused on encouraging of researches and development in obtaining technologies or methods for GHG emission reduction (Fiddaman, 2007).

Some researches should be done in reduction GHG emission from biodiesel production chain. Some research are (1) reduction GHG emission from palm oil cultivation, (2) increasing palm oil production with minimum land expansion for palm oil estate, (3) reduction GHG emission from palm oil milling processing and (4) reduction GHG emission from refinery and production of palm oil biodiesel (Tan, Muhammad et al. 2012).

Some reduction technologies were identified along palm oil biodiesel production chain. These technologies were, (1) application of superior seed (Halimah, Surif et al. 2012), (2) composting empty fruit bunch (EFB)

(Loekito 2002), (3) methane capturing from POME capture (EPA 2011, Prasetya, Arkeman et al. 2013), (4) combustion of biomass to produce electricity (Darrow, Tidball et al. 2014) and (5) reaction between using Palm Fatty Acid Destilate (PFAD) and glycerol as feedstock for biodiesel production biodiesel (Cho, Kim et al. 2013). Among these technologies, methane capture was biggest contributor in GHG emission reduction. Methane capture could reduce GHG emission potentially by more than 70 % (Prasetya, Arkeman et al. 2013). Therefore, methane capture technology was a key technology for GHG emission reduction in palm oil biodiesel production.

Aim of the paper was technology policy assessment for methane capture development. The assessment would be focused on analysis of technology status, capabilities, climate and determining technology acquisition strategy for methane capture development.

2. Methodology

2.1 *Technology Policy Assessment Framework*

Management of Technology (MOT) was employed to assess technology policy for methane capture development. MOT was a framework for Technology Based Regional Development (Alkadri, Riyadi et al. 2000). The approach was started by analysis of level of technology status, technology capabilities and technology climate. Based on the analysis, If-Then Rule was developed to determine appropriate technology acquisition strategy. The framework was show in Figure 1.

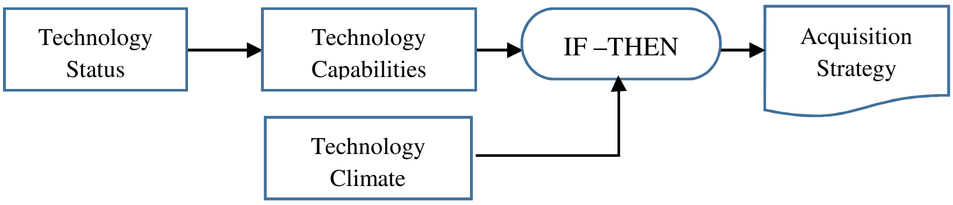

Figure 1. Framework of Technology Policy Assessment

T[illegible] try. Technology status analysis show level of technological progress among regions or industry (Alkadri, Riyadi et al. 2000). The analysis was conducted by comparing current technology application with state of the art of the one. Comparison was conducted on four components of technology, i.e.: Technoware, Humanware, Infoware and Orgaware (THIO). The components were classified into 7 level of degree of sophistication. Degree of sophistication for each component of technology show in Table 1.

Table 1. Degree of Sophistication of Technology Components of Methane Capture

No.	Technoware	Humanware	Infoware	Orgaware	Scale
1.	CL Flaring	Operating Tool	General information	Small company with small market	N
2.	CL Steam	Install tool	Technical information	Small company acting as sub-contractor	VL
3.	CL Electricity	Maintenance	Tool selection	Small company with market network	L
4.	CL CHP & CT Flaring	Management	Using Effectively	Company with market network and able to seek new market	M
5.	CT Steam	Modification	Knowledge Enhancement	Competitive company	H
6.	CT Electricity	Repairing	Repairing tool information	Company success developed fast and stable	VH
7.	CT CHP	Innovation	Specific tool Assessment	Company as leader in specific field	P

Note: CL: Covered Lagoon and CT: Closed Tank
Scale: N=Most Low, VL = Very Low, L=Low, M=Medium, H=High, VH=Very High, P=Perfect
Sumber : (Alkadri, Riyadi et al. 2000) with modification

Technology capabilities is ability to seek and utilize technology for strategic advantage (Rush, Bessant et al. 2007). There are some method in assessing technology capabilities, such as intellectual capital, organization maturity models and knowledge management (Alizadeh 2012) and stage of technology component developing (Alkadri, Riyadi et al. 2000). Stage of technology component developing was employed to assess technology capabilities, due to the method using same parameters with analysis technology status and climate. Stage of developing of technology components was show in Table 2.

Table 2. Stage of Technology Components Developing

Stage	Technoware	Humanware	Infoware	Orgaware	Scale
I	Research	Growing	Purchasing	Conceptualizing	N
II	Development	Telling	Screening	Preparing	VL
III	Testing	Teaching	Classification	Designing	L
IV	Demonstration	Educating	Association	Establishment	M
V	Production	Training	Analysis	Operation	H
VI	Diffusion	Strengthening	Synthesis	Directing	VH
VII	Substitution	Improvement	Emulation	Evolving	P

Sources : (Alkadri, Riyadi et al. 2000) with modification

Technology climate is external condition which affect to technology transformation (Alkadri, Riyadi et al. 2000). Technology climate assessment was directed to explore a conducive condition for technology development. Seven groups of data could be utilized to assess technology climate, i.e.: (1) general condition of technology climate, (2) technology activities facility, (3) partial indicators, (4) evaluation of restructuring and productivity, (5) human resources development, (6) innovative level of industry, and (7) regulation and incentive (APCTT 1986). Also, technology climate assessment should include problems related to technology development. The problems were grouped into six categories, i.e.: (1) availability of physical facilities of technology, (2) human capabilities (3) information system and documentation,(4) institutional and regulation system, (5) technology culture and (6) regional inter-connection limitation (Alkadri, Riyadi et al. 2000).

In this research, technology climate analysis was bounded in assessment of regulation and incentive for THIO. Regulation analysis was conducted to assess level of technology policy supporting (Hayun, Machfud et al. 2013) for implementation of methane capture technology. Technology policy instrument contain of procurement, (2) voluntary standards and incentives, and (3) regulations in the context of technology life cycles (Cohenn and Amorós 2014, Watanabe and Salmador 2014). In context carbon capture and storage (CCS) technology, there are several technology policy instruments, such as incentivizing operations, costs and risks mainly borne by private sector, subsidizing abatement or penalizing emissions and targeting CCS ‑ specific incentives or technology ‑ neutral incentives (Heidug 2012). Based on several instrument, we formulated and utilized three instrument on THIO, i.e.: regulation or incentive for purchasing technology components, formulation standard and risk covered. Each regulation would be assessed by expert into seven scale as both in technology status and climate. Criteria for technology climate analysis, were show in Table 3.

Table 3. Criteria for Technology Climate Analysis

Technoware	Humanware	Infoware	Orgaware
Technology Purchasing	Human Resource Recruitment	Information Acquisition	Organization establishment
Technology Standard	Competency standard	Information Standard	Organization Standard
Technology Risk	Human Resources Risk	Information Risk	Organization Risk

Sources: processed from (Alkadri, Riyadi et al. 2000) and (Heidug 2012)

2.2 *Data Collection*

Data was collected by literature review, report synthesis and expert assessment. Literature review was focused on exploring of methane capture type and the state of the art. Report synthesis was conducted to describe current methane capture implementation. Three experts were selected to judge level of technology component for analysis of technology status, capabilities and climate. Three expert represented technology development stakeholder, i.e.: researcher, government officer and businessman.

Each expert was given a questionnaire and assessed component of technology into seven scales judgement. Seven scales were Perfect, Very High, High, Medium, Low, Very Low and None/Most Low (Yager 1993). In aggregation purpose, negation operation of these scales were determined. The negation operation of these scale were None, Very low, Low, Medium, High, Very High, and Perfect respectively.

2.3 *Data Analysis*

Analysis of level of technology status and capabilities was utilized Non-Numeric Multi-Expert Multicriteria Decision Making (Non-Numeric ME-MCDM). ME-MCDM was used to evaluate and select alternatives in non-numeric scale (Yager 1993, Suprihatini, Sa'id et al. 2004). The method contain of two aggregation, i.e.: criteria and expert aggregation (Rukmayadi and Marimin 2000, Nurhasanah 2006).

Criteria aggregation (V_{ij}) is minimum value from maximum operation (⋁) between judgement value on criteria i by expert j in alternative k ($V_{ij}(a_k)$) and Negation of alternative weight of k (W_{ak}), therefore the equation was write as follow.

$$V_{ij} = \min\left[Neg\ (W_{ak}) \vee V_{ij}(a_k)\right] \quad (1)$$

Expert aggregation (V_i) is maximum value from minimum operation (∧) between experts weight (Q_j) and ordered alternative aggregation from highest to lowest (b_j), therefore the equation was show as follow.

$$V_i = f(V_i) = Max\left[Q_j \wedge b_j\right] \quad (2)$$

Expert weight was calculate by using equation as follow.

$$Q_k = Int\left[1 + \left(k * \frac{q-1}{r}\right)\right] \quad (3)$$

Where, Q_k is notation for expert weight, *Int* is integer number, k is index, number of judgement scale (q), and amount of experts (r).

Also, Non-Numeric ME-MCDM was employed to analyze level of technology climate. In this analysis, we assumed three type of regulations as alternatives. Three selected experts were asked to assess three of alternative in each technology component (THIO) into seven scales of judgement. The expert judgements were aggregated both criteria aggregation, expert and alternative. These aggregation described a level of technology climate.

Level of technology status, capabilities and climate were combined to determine appropriate technology acquisition strategy. IF-Then Rule was formulated to determine technology acquisition strategy. If-Then rule contain of two parts, i.e.: the part before THEN is called antecedent and after it consequent (possibly also succedent) (Novák and Lehmke 2006). In this research, antecedent part contained of three argument which related to level of technology status, capabilities and climate, while consequent was technology acquisition strategy. Format of If-Then Rule was show as follow.

IF technology status is [j] AND technology capabilities is [i] AND technology climate is [x] THEN technology acquisition strategy is [a]

Value each argument (technology status, capabilities and status) was seven scale of judgement, therefore there was 343 if-then rules, while the variation of technology strategies were three only, i.e.: buying strategy, strategic alliance and making(Alkadri, Riyadi et al. 2000). Determining consequent part (technology acquisition) from 343 variation of antecedent, were conducted by converted the seven of judgment scale into integer number (1 until 7). The highest scale (P) was converted into 7 and lowest scale was converted into 1. Then, each converted number was added and total number was integer number from 3 to 21. The total number was utilized to determine technology acquisition strategy. The range of total number for buying strategy, strategic alliance and making were 3-10, 7-17 and 14-21 respectively. Probability of each if-then rule was calculated by adopted Triangle Fuzzy Number (TFN). The adoption of TFN for probability calculation was show as follow.

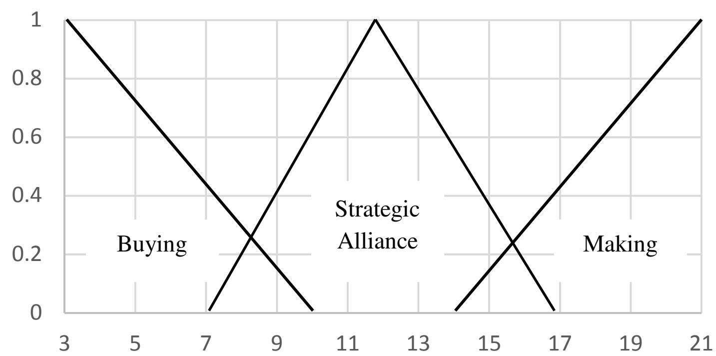

Figure 2. Adopted TFN for Probability Calculation

By adopted TFN concept, probability of 343 If-Then Rules was calculated. Experts was asked to evaluate rules with low probability values (less than 0.3) in ensuring accuracy of the one. Some example of rules from 343 rules was show in Table 4.

Table 4. Some If-Then Rules for Technology Acquisition Strategy Determination

Antecedent			Consequent	Probability
Status	Capabilities	Climate	Acquisition Strategy	
N	N	N	Buying	1.00
N	N	N	Buying	0.83
VL	VL	VH	Strategic Alliance	0.67
VL	VL	P	Strategic Alliance	0.33
P	M	ST	Making	0.33
P	M	P	Making	0.50

Sources: data analysis

3. Result

3.1. *Research and Implementation of Methane Capture in Indonesia*

Methane capture is methane trapping and utilizing technology. In palm oil biodiesel production chain, the technology is utilized to capture methane from palm oil mill effluent (POME). POME is produced by wet process of palm oil mill (Wu, Mohammad et al. 2009). It is estimated that for each ton of crude palm oil that is produced, 5–7.5 ton of water are required, and more than 50% of this water ends up as palm oil mill effluent (POME) (Sairan and Aman 2007, Wu, Mohammad et al. 2009).

POME is biggest contributor on biomethane (CH_4) emission from biodiesel production chain. POME was mainly consist of biomethane (CH_4) and carbon dioxide (CO_2) in 65:35 ratios (Sairan and Aman 2007, Lam and Lee 2011) and approximately 28m^3 of gases were emitted from 1 ton of POME (Lam and Lee 2011). Non-recovered biomethane emission from POME contributed the highest impact towards the environment (climate change category) and therefore makes the overall processes not environmentally friendly (Subramaniam, Ngan et al. 2008).

Methane capture technology consist of sub component of technologies, i.e.: POME treatment, methane trap and methane utilization. There are some POME treatment method such as aerobic treatment, membrane treatment system and evaporation (Poh and Chong 2009), also anaerobic treatment such as conventional anaerobic treatment, anaerobic filtration, fluidized bed reactor, up-flow anaerobic sludge blanket (UASB) reactor (Najafpour, Zinatizadeh et al. 2006), continuous stirred tank reactor (CSTR) and anaerobic contact digestion (Poh and Chong 2009). Methane trap technology contain of four types, i.e.: covered lagoon, close tank (EPA 2011), open tank and Covered in Ground Anaerobic Reactor (CIGAR) (Ridlo 2011). While, biomethane was utilized for several purposes, such as flaring, electricity, steam production and Combined Heat and Power (CHP) (EPA 2011), also for lighting, cooking, biofuel and H_2 production (Ridlo 2011).

In Indonesia, several research on POME treatment and biomethane utilization were conducted. Some researches in POME treatment were study phytase activity and phosphorous content on fermented dry POME (Purwadaria, Irayati et al. 2003), effect time fermentation to biogas production (Mujdalipah, Dohong et al. 2014), pattern of biogas production from POME (Suprihatin, Sa'id et al. 2013) and evaluation technology content POME Treatment (Sarono, Sa'id et al. 2014). In biomethane utilization, most of researches focused on utilization it as electricity purposes (Febijanto 2010, Febijanto 2011, Sarono, Sa'id et al. 2014).

Recently, about 5.5 % of total palm oil milling company in Indonesia, have been implemented methane capture. Total palm oil capacity which have been implemented the technology approximately 2.775 ton FFB per hour (Ridlo 2011). Covered Lagoon was the most technology which have been implemented (about 40 % from total methane capture).

3.2. *Analysis Technology Status, Capabilities and Climate*

Analysis status technology, capabilities and climate need two type of expert judgement i.e.: weight of criteria (THIO) and expert assessment for each methane capture component. Experts were asked to assess into a certain questionnaire. Based on in depth interview with selected expert, component technology (THIO) weight were H, P, VH and H respectively, therefore negation of the weight ($Neg(W_{ak})$) were L, N, VL and L. Expert judgement of technology status was show as follow.

Table 5. Expert Judgement on Technology Status of Methane Capture

Expert	**CRITERIA**			
	Technoware	**Humanware**	**Infoware**	**Orgaware**
Expert 1st	M	H	VH	M
Expert 2nd	M	H	H	M
Expert 3rd	H	VH	H	M

Sources: experts' judgement

Criteria aggregation of Table 5 was calculated by using equation (1). Criteria Aggregation from expert 1st, expert 2nd and expert 3rd were represented with V_1, V_2 and V_3 respectively. Result of criteria aggregation from Table 5 were M, M and M. Illustrations of criteria aggregation were show as follow.

V_1 = min [L v M, N v H, VL v VH, L v M]
= min [M, H, VH, M]
= M

V_2 = min [L v M, N v H, VL v H, L v M]
= min [M, H, H, M]
= M

V_3 = min [L v H, N v VH, VH v H, L v M]
= min [H, VH, H, M]
= M

Expert aggregation was calculate by using equation (2) and equation (3). Weight of each expert were calculated first. Q_1, Q_2 and Q_3 were notation for weight of expert 1st, expert 2nd and expert 3rd respectively which were calculated by using equation (3). The expert weights were L, H and P respectively. Expert aggregation calculation need result of criteria aggregation and expert weights, then the calculation was used equation (2). The final aggregation for technology status was M (medium). The expert aggregation was show as follow. Result of criteria aggregation were x_j was M, M, M, therefore b_j = M, M, M.

$f(V_1)$ = max [L ∧ M, H ∧ M, P ∧ M]
$f(V_1)$ = max [L, M, M]
$f(V_1)$ = M (Medium)

Table 6. Expert Judgment for Technology Capabilities and Result of Aggregation

EXPERT	**CRITERIA**			
	Technoware	**Humanware**	**Infoware**	**Orgaware**
Expert 1st	M	H	H	H
Expert 2nd	M	H	VH	H
Expert 3rd	H	H	H	H
Result Summary				
Weight	H	P	VH	H
Negation	L	N	VL	L
Criteria aggregation		M	M	H
Expert Weight		L	H	P
Final Aggregation		M (Medium)		

Sources: experts' judgement and analysis

Analysis of technology capabilities was conducted as technology climate step. Two aggregation were operated to analyze technology capabilities level. Data and summary of calculation was show in Table 6. Data was obtained by expert judgement processing, while all equation as mentioned before were employed to identify level of technology capabilities level.

Analysis of technology climate was conducted by non-numeric ME-MCDM with three alternatives. The alternatives were regulation or incentive for technology purchasing, standard formulation and risk management. Each expert was asked to assess THIO component of three alternatives. Data expert assessment of technology climate of methane capture was show in Table 7.

Table 7. Expert Assessments of THIO on Three Types of Regulation

Expert	Policy	CRITERIA			
		Technoware	Humanware	Infoware	Orgaware
Expert 1st	Purchasing	M	M	H	H
Expert 2nd	Purchasing	M	H	H	M
Expert 3rd	Purchasing	L	M	M	H
Expert 1st	Standard	VL	H	H	H
Expert 2nd	Standard	VL	M	H	M
Expert 3rd	Standard	VL	M	H	H
Expert 1st	Risk	M	H	M	M
Expert 2nd	Risk	L	H	M	H
Expert 3rd	Risk	L	M	M	M

Sources: expert judgement

Two step aggregation was conducted in technology climate level analysis. First step, both criteria and expert aggregation were done for tree alternatives, therefore three aggregation results were obtained. Then, second aggregation was operated to formulate final result on technology climate level. Summary of result analysis was show as follow.

Table 8. Summary of Technology Climate Analysis

Step 1st : Criteria and Expert Aggregation			
Regulation/Incentive for Technology Purchasing			
Criteria aggregation	M	M	L
Expert Weight	L	H	P
Aggregation	M (Medium)		
Regulation/Incentive for Technology Standard Formulation			
Criteria aggregation	L	L	L
Expert Weight	L	H	P
Final Aggregation	L (Low)		
Regulation/Incentive for Technology Risk Management			
Criteria aggregation	L	L	M
Expert Weight	L	H	P
Final Aggregation	L (Low)		
Step 2nd : Alternative Aggregation			
Alternative Aggregation	**M**	**L**	**L**
Final Aggregation	**L (Low)**		

Sources: analysis

Table 8 show summary of technology climate analysis which contained of two step aggregations. Aggregation result for technology purchasing, standard and risk management were medium, low and low respectively. Second step, aggregated result which obtained from first step into single value. The final aggregation for level of technology climate was low.

3.3 *Technology Acquisition Strategy*

If-Then rule was designed to identify appropriate technology acquisition strategy. There were 343 rules which were possible combination among technology status, technology capabilities and technology climate. The rule, called linguistic descriptive (LD). A LD relate both explicit and implicit knowledge (Novák and Lehmke 2006). Previous analysis provided information of level of technology status, capabilities and climate, which were utilized to identify appropriate technology acquisition strategy. Querying 343 rule with certain level of three components antecedent, obtained appropriate strategy. The match rule was show as follow.

IF Technology Status is Medium AND Technology Capabilities is Medium AND Technology Climate is Low THEN Technology Acquisition Strategy is Strategic Alliance, Probability 0.33.

Strategic alliance is appropriate strategy for methane capture development recently. The strategy was expected to improve technology capability especially technoware. Research in methane trap technology should be enhanced in substitution covered lagoon into tank technology. Also, strategic alliance should be focused on enhancement technology climate through knowledge sharing in acquisition policy, standard formulation and risk management of technology implementation.

4. Conclusion

Analysis result of technology policy for methane capture technology show level technology status, and technology capabilities were medium, while technology climate were low, therefore strategic alliance in technology development was recommended as technology acquisition strategy. The strategy was expected to improve technology capability and technology climate.

The research covered non-numeric data, but some data in technology climate, were numeric data, therefore we recommended study on combination between non-numeric and numeric data in enhancing this research. Also, we recommended the next study should be enriched with some technology climate conditions and six groups of technology problems.

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