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Assessment of enablers and disablers of environment-food-energy-water nexus in biomass value chain

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Abstract. The study aims to understand biomass value chains (BVC) in Malaysia, specifically those involving the use oil palm waste such as empty fruit bunch (EFB), palm oil mill effluent (POME) and oil palm trunks (OPT). This particular type of biomass source was selected as it is very abundant and is a major feedstock in existing biomass value chains in the country. The research uses survey methodology to obtain data related to BVCs by surveying relevant stakeholders. From the information obtained in Section 1 and Section 2 of the survey conducted, we were able to assess the enablers and disablers of environment-food-energy-water (EFEW) nexus in biomass value chain, which is the main research objective. Other than that, the raw data from survey is analyzed with SPSS statistical analysis methods to determine the relationship between technology, policies and role of government and private sector with the implementation of sustainable BVCs. Based on this, we found that the R value obtained was 0.759 with an R-square value of 0.575. From the Pearson correlations, we found that X3 (referring to role of private sector) showed the highest correlation and was the only statistically significant variable obtained based on the model. Finally, a comparative study on BVC's and fossil fuel value chain (FFVC) was also performed. From this comparison, we note that BVCs and FFVCs differ significantly in terms of carbon footprint, economic feasibility, technology, government and private role, policies, infrastructure, and volatility of resource.

Introduction

Biomass value chains (BVCs) refers to a network of infrastructure and technology designed to convert low value raw materials, such agricultural and forestry residue, to high value products [1]. BVCs typically undergo four main steps which are crop harvesting, biomass storage, logistical transportation, and biomass processing. Occasionally, pre-processing of biomass such as drying, and pelletizing may be necessary to increase the energy density of products. This is seen as being economical as it allows for easy storage and transportation.

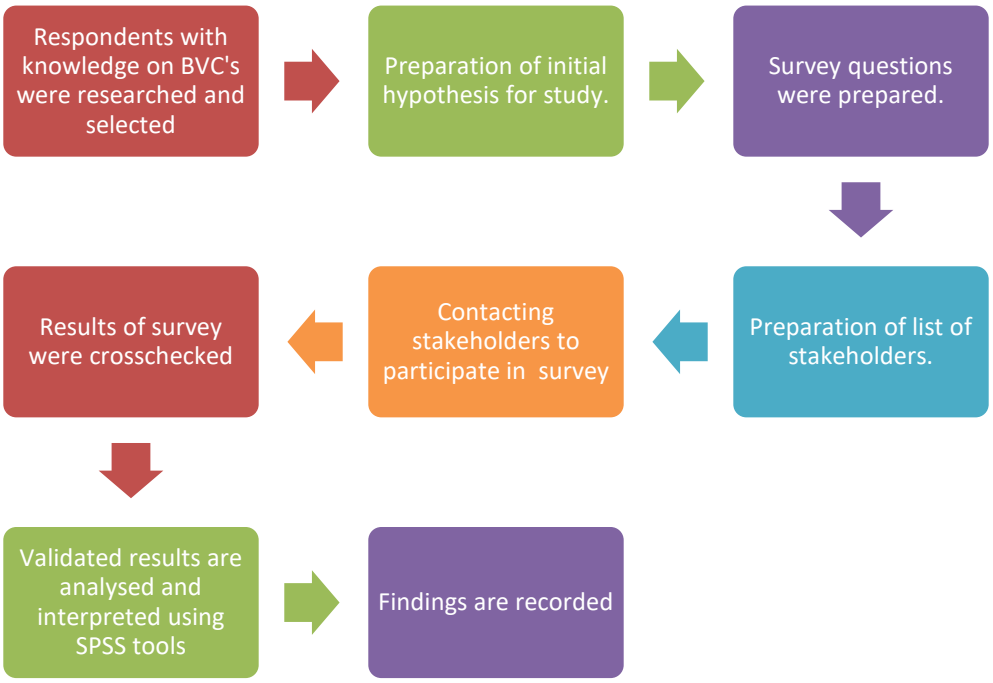
The environment-food-energy-water (EFEW) nexus, on the other hand, is a systems-thinking approach that could holistically and critically address climate change [2]. The EFEW nexus provides us a useful framework to carefully assess the impacts of existing biomass value chains on these 4 interconnected and interdependent sectors (environment, food, energy, and water). Additionally, the EFEW nexus is considered to be able to anticipate unforeseen consequences towards our natural resources and seek common ground for various conflicting factors present in BVC's [3] . The enablers and disablers of EFEW refers to the mindsets, attitudes and structures

that encourage or discourage implementation or adoption of sustainable practices, which in this case, within BVCs.

Therefore, this study aims to provide meaningful insight on the challenges of implementing sustainable BVCs within the context of EFEW by surveying local producers, processors, and distributors of biomass, as well as receive input from researchers and organizations. This will shed light onto the actual factors that enable and disable implementation of sustainable BVCs in Malaysia which can then be utilized to provide recommendations to sustainably optimize existing BVCs. In effect, biomass sources, specifically that from oil palm waste, will be able to better compete as a viable alternative source of energy and green products.

Materials and Methods

Methodology



Selection of respondents

The respondents were selected by identifying groups or individuals that may have specific knowledge on biomass value chains. These include the stakeholders involved in actual biomass value chains in Malaysia. The stakeholders were identified as being the biomass producers, processing plants, researchers, organizations, and policy makers.

Table 1: Overview of relevant stakeholders in biomass sector

FUNCTION	NO. OF RESPONDENTS
FARMER	3
REPRESENTATIVE FARMERS' ORGANIZATION	1
CUSTOM HARVESTER	4
REPRESENTATIVE FROM INDUSTRY	3
POLICY MAKER	1
RESEARCHER	2
TOTAL	**14**

Survey and Interviews

A survey was prepared which consists of two main sections that included 50 rating type questions and essay type questions. The rating questions are divided into 7 individual parts. The data collected will then be analyzed through SPSS methods to derive the specific relationships and correlations between the variables and gauge if the initial hypothesis can be accepted or rejected. For interview section, a sample of the rating type or Likert scale questions is used in the survey.

Table 2: Breakdown in survey questionnaire

Section Type	Section Parts	Section Name	No. of questions
Ratings	Part 1	Biomass Industry in Malaysia	10
	Part 2	Biomass Value Chains in Malaysia	10
	Part 3	Challenges in Implementing Biomass Value Chains	10
	Part 4	Technology in Biomass Sector	5
	Part 5	Role of Government in	5
	Part 6	Biomass Industry	5
	Part 7	Role of Private Sector in Biomass Industry	5

Results and discussion

A total of 15 respondents from various segments of the biomass industry were recorded. The breakdown of respondents from the varying stakeholder segments in the biomass industry is as shown in Figure 1.

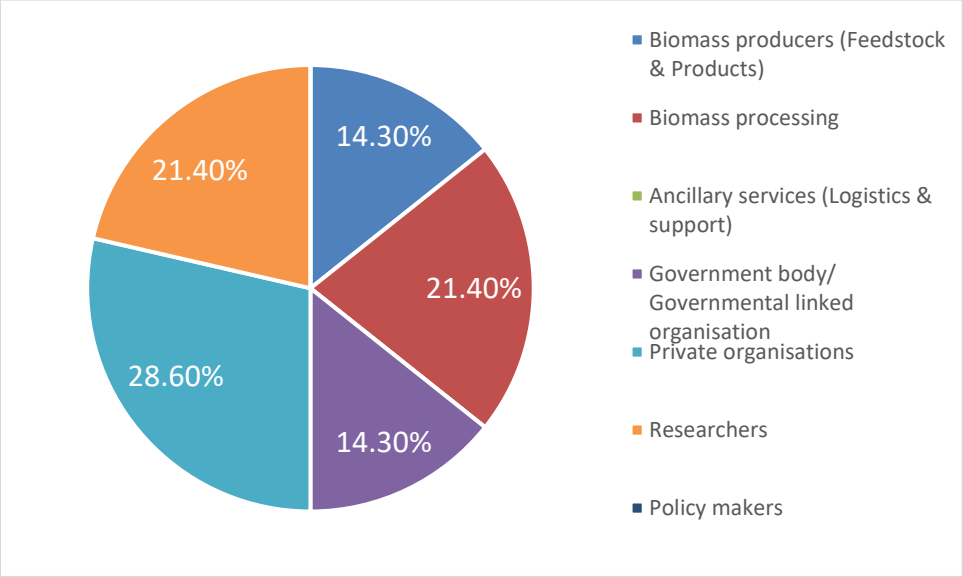
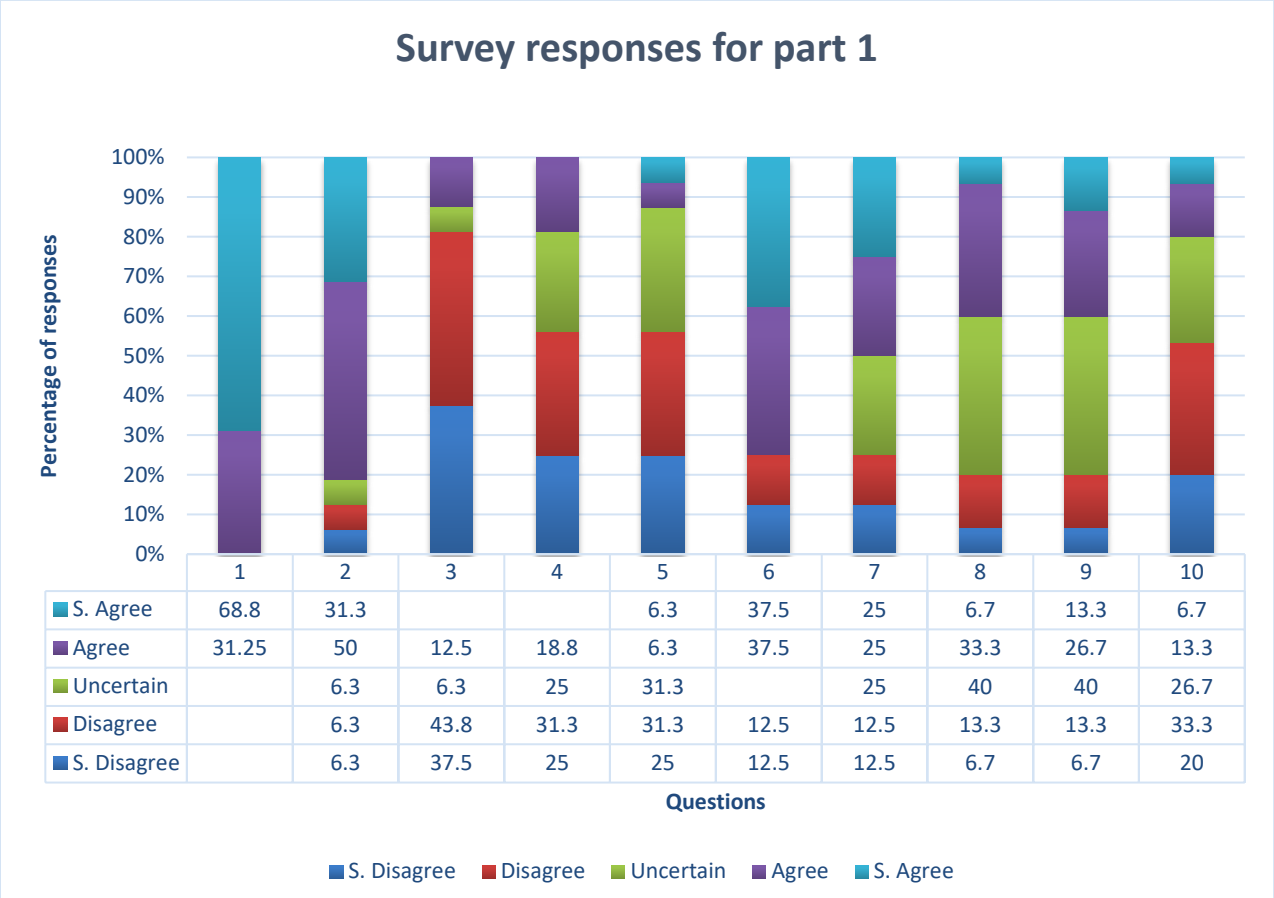


Figure 1: Stakeholder segments that participated in survey

Part 1: Biomass Industry in Malaysia

The percentage of responses in Part 1 for each question can be observed in Figure 2. The information collected from the data is grouped into two parts which are (i) Biomass sources and the extent of their use in Malaysia and (ii) Utilization of biomass as an energy source.



	1	2	3	4	5	6	7	8	9	10
S. Agree	68.8	31.3			6.3	37.5	25	6.7	13.3	6.7
Agree	31.25	50	12.5	18.8	6.3	37.5	25	33.3	26.7	13.3
Uncertain		6.3	6.3	25	31.3		25	40	40	26.7
Disagree		6.3	43.8	31.3	31.3	12.5	12.5	13.3	13.3	33.3
S. Disagree		6.3	37.5	25	25	12.5	12.5	6.7	6.7	20

Figure 2: Responses for part 1 of survey

Biomass Sources and The Extent of Their Use in Malaysia

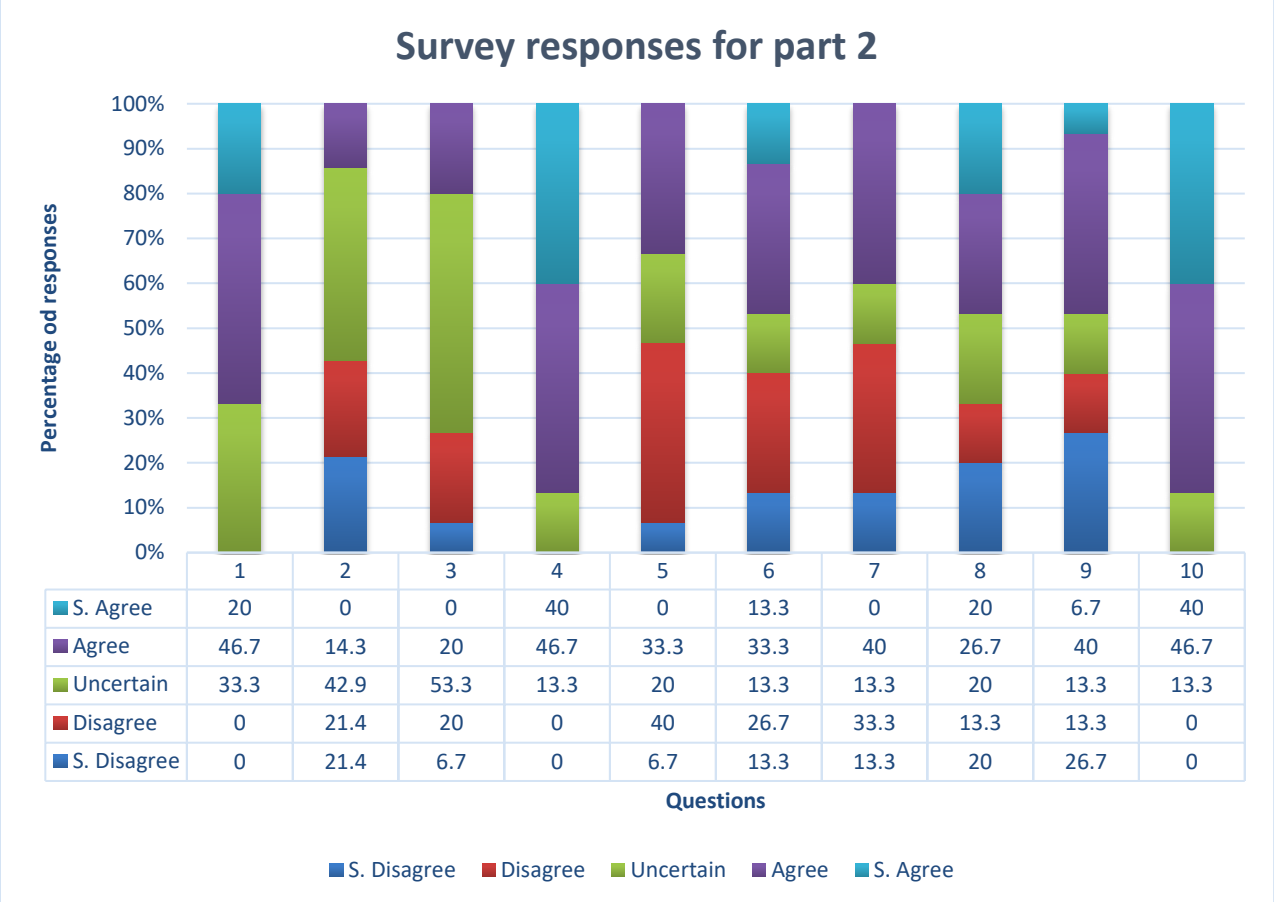
It is found that all respondents agrees that agricultural sector contribute most of biomass generated. In other words, municipal waste, urban garbage, and waste from animal breeding are less significantly utilized. Most of the respondents also agree that energy crops are not largely developed as a biomass source in Malaysia. As a whole, the respondents agree that the agricultural waste currently produced is not being effectively utilized as biomass.

Biomass As Energy Source

Most respondents agree on the fact that energy generation from biomass sources are not as widely developed as solar energy in Malaysia. However, energy from biogas and BioCNG plants are locally available through the national grid, although their capacity may not be very high. This can be corroborated from information obtained from the SEDA portal. Additionally, all experts agree that the biomass industry in Malaysia is focused on the production of solid biofuels and briquettes, which are mostly made for import and typically not consumed locally.

Part 2: Biomass Value Chains in Malaysia

The percentage of responses in Part 2 for each question can be observed in Figure 3.



	1	2	3	4	5	6	7	8	9	10
S. Agree	20	0	0	40	0	13.3	0	20	6.7	40
Agree	46.7	14.3	20	46.7	33.3	33.3	40	26.7	40	46.7
Uncertain	33.3	42.9	53.3	13.3	20	13.3	13.3	20	13.3	13.3
Disagree	0	21.4	20	0	40	26.7	33.3	13.3	13.3	0
S. Disagree	0	21.4	6.7	0	6.7	13.3	13.3	20	26.7	0

Figure 3: Responses for part 2 of survey

Opinion on Environmental Sustainability of Existing BVCs

There is some significant uncertainty among the respondents with regards to the environmental sustainability of BVCs currently implemented. This is gauged as a total of 42.9% and 53.3% of respondents were uncertain, when they were asked on whether or not existing BVCs in Malaysia pose concerns towards resource sustainability and negatively impacts the environment. This

indicates that the awareness on the adverse environmental effects of unsustainably implemented BVCs may not be very high among respondents.

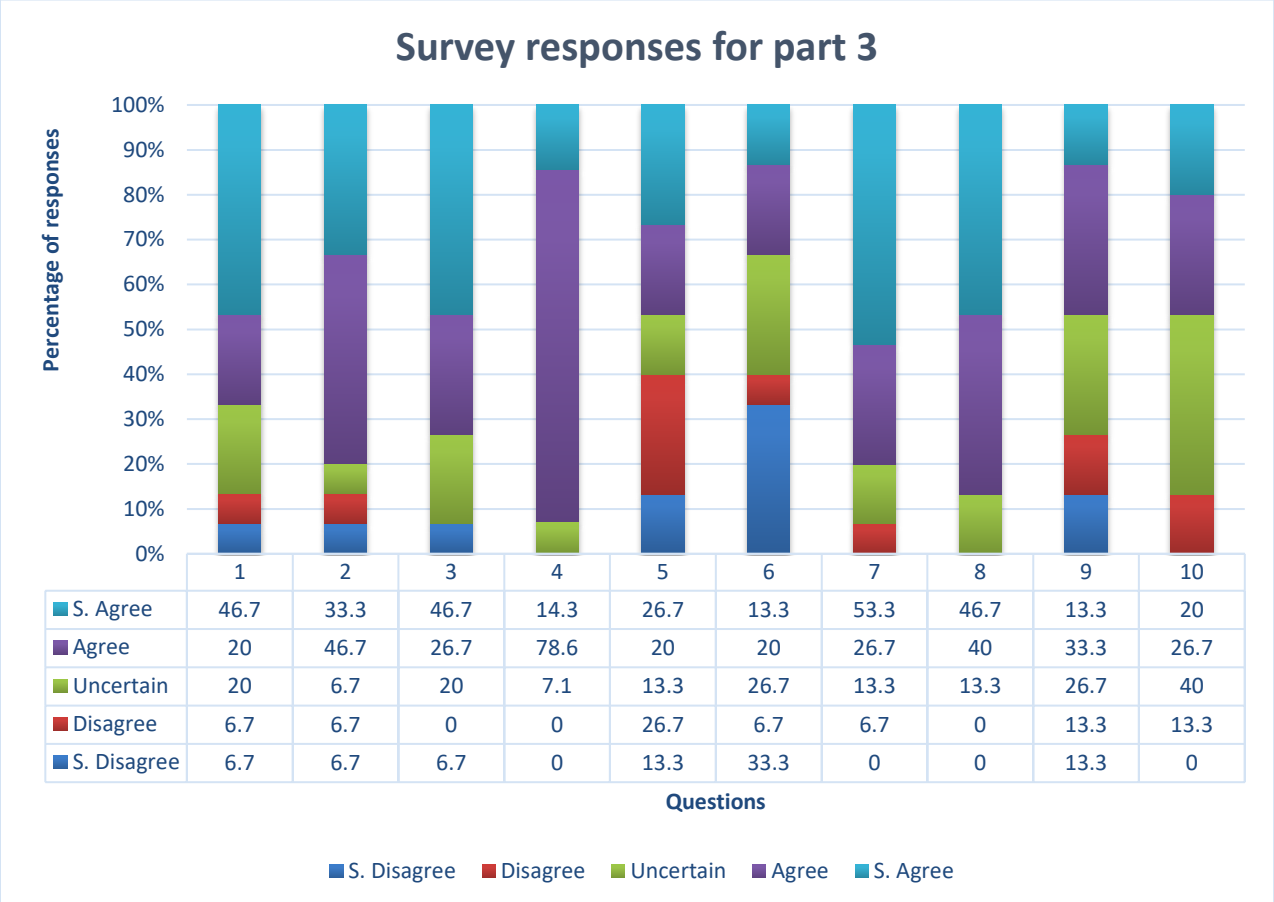
Environmental Concerns Related to BVCs

A majority of respondents agree that BVCs are definitively more environmentally friendly compared to fossil fuel value chains. They also disagree that BVCs produce significant carbon footprint. This is consistent with various studies that have proven the impact of fossil fuels and their value chains on the environment.

Despite this, they do believe that there are some environmental concerns involved such as the water used for irrigation of crops and steam in processing plants may be used unsustainably. For the other environmental issues put forth, the results are less obvious. 46.7% agree on the issue of unsustainable energy use in biomass processing and water pollution from fertilizers and waste from biomass production. On the other hand, 46.7% disagree that competition for land between biomass cultivation and food crops is a major concern.

Part 3: Challenges in Implementing Biomass Value Chains in Malaysia

The percentage of responses in Part 3 for each question can be observed in Figure 4. The goal is to determine the difficulties and challenges in conducting and implementing BVC in Malaysia's biomass sector in an efficient and environmentally friendly way.



	1	2	3	4	5	6	7	8	9	10
S. Agree	46.7	33.3	46.7	14.3	26.7	13.3	53.3	46.7	13.3	20
Agree	20	46.7	26.7	78.6	20	20	26.7	40	33.3	26.7
Uncertain	20	6.7	20	7.1	13.3	26.7	13.3	13.3	26.7	40
Disagree	6.7	6.7	0	0	26.7	6.7	6.7	0	13.3	13.3
S. Disagree	6.7	6.7	6.7	0	13.3	33.3	0	0	13.3	0

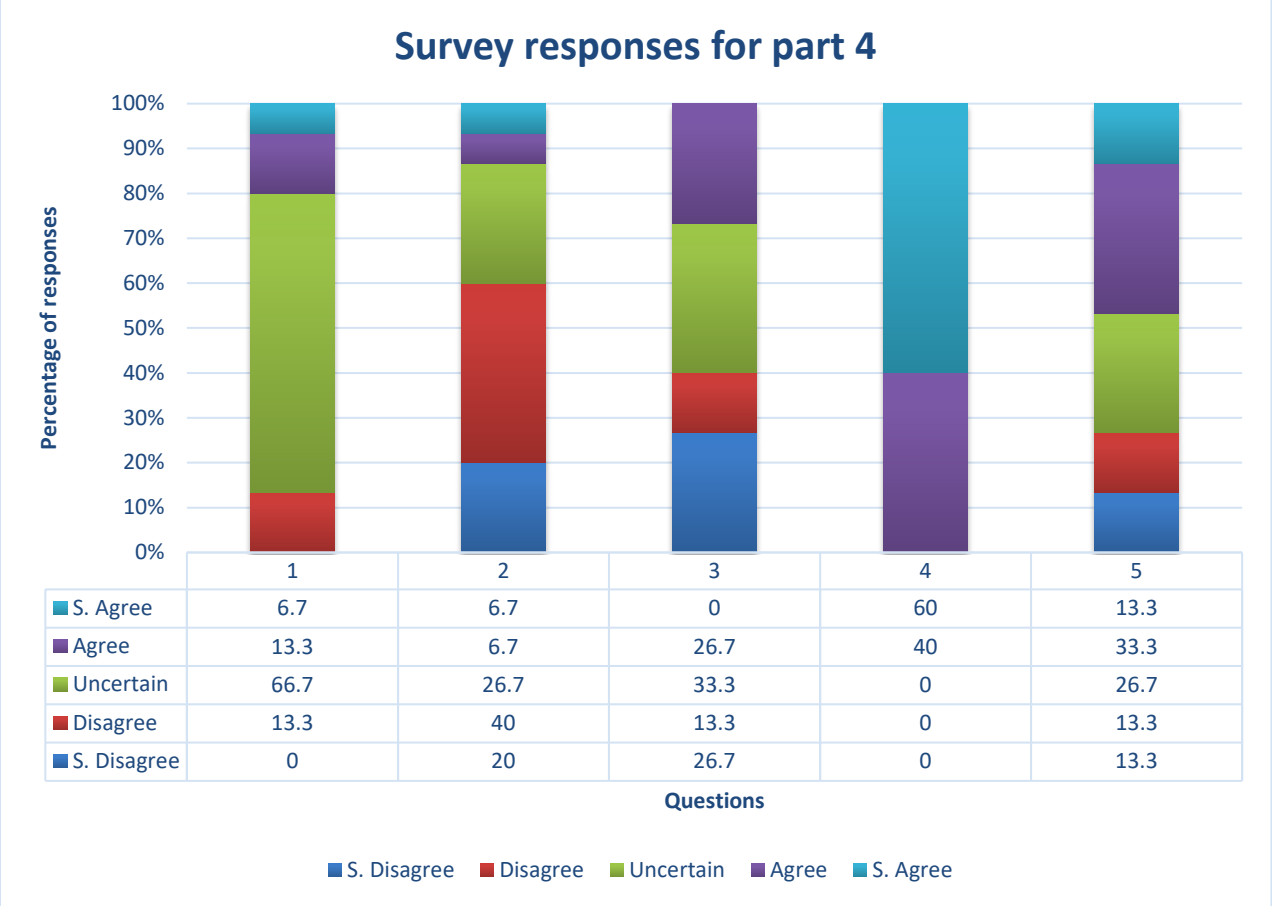
Figure 4: Responses for part 3 of survey

All the respondents agree that the implementing BVCs and being involved in the sector itself comes with several challenges. 66.7% believed that the uncertainties in biomass supply could be one of the main challenges. Additionally, 92.9% believe that involvement in the biomass sector may be hindered due to cost and economic reasons. Other than that, the lack of technology and insufficient policies are believed by most respondents to be a major challenge. This corresponds with our initial outcome hypothesis, whereby technology and policy are identified as being a factor that affects sustainable implementation of BVC.

The respondents mostly agreed that the nature of current pre-processing of biomass which utilizes large amount of heat power and the issue of scarcity and long distance between facilities is a major challenge that affects sustainability of BVC. However, results were more mixed when it came to other possible internal factors. 46.7% agree that harvesting/ collection activities require massive amounts of water, land, and energy, while 40% disagree. Additionally, 40% disagree that storage of biomass is not carbon free, while 33% agree. Besides that, 46.7% agree that the nature of biomass materials that are usually high volume and deteriorative further increases transportation needs that lead to environmental damage while 40% were uncertain.

Part 4: Technology in Malaysian Biomass Sector

The percentage of responses in Part 4 for each question can be observed in Figure 5.



	1	2	3	4	5
S. Agree	6.7	6.7	0	60	13.3
Agree	13.3	6.7	26.7	40	33.3
Uncertain	66.7	26.7	33.3	0	26.7
Disagree	13.3	40	13.3	0	13.3
S. Disagree	0	20	26.7	0	13.3

Figure 5: Responses for part 4 of survey

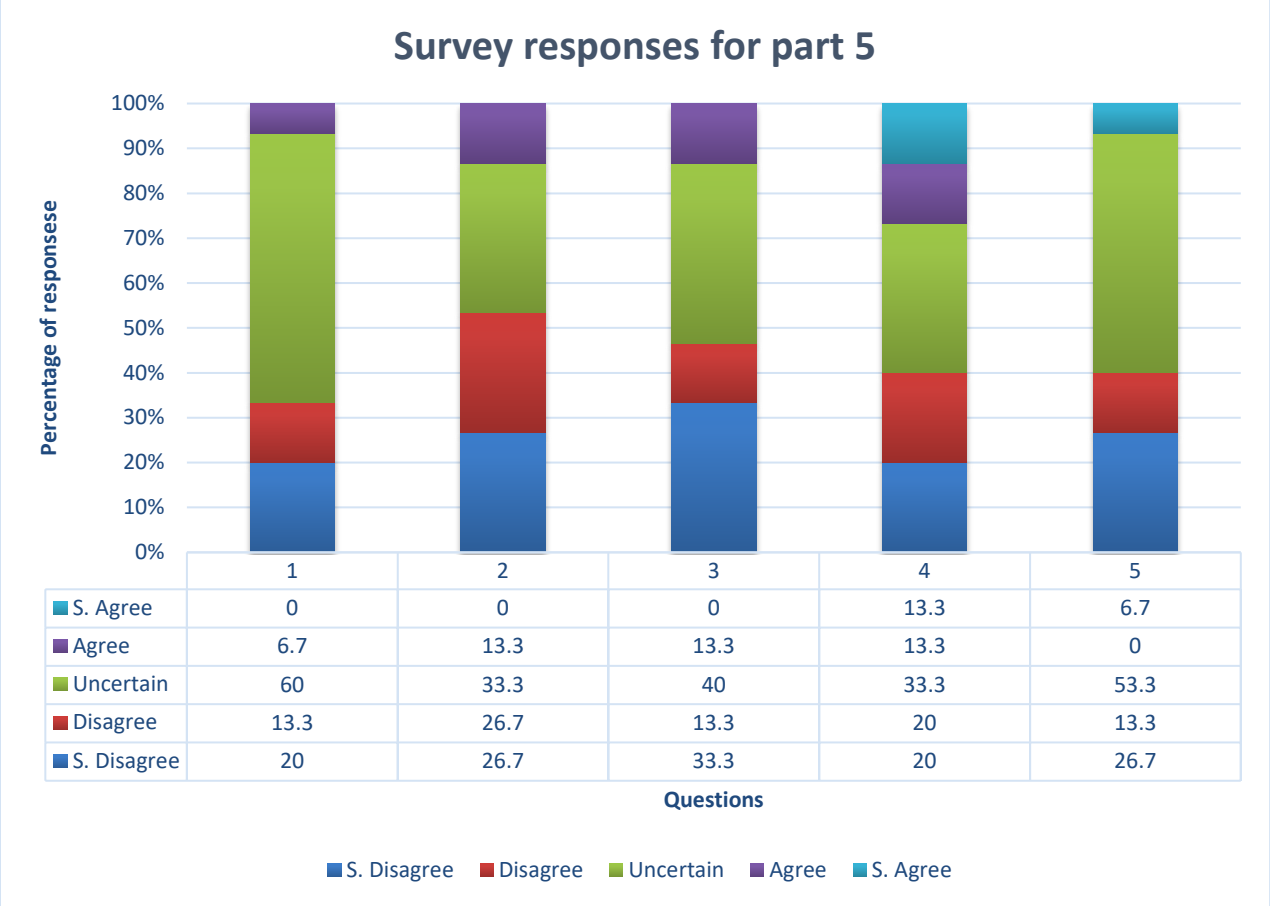
Based on the survey responses, it is evident that most of the respondents seem to be unaware of new technology currently being used or developed within the biomass industry. This is because 66.7% responded that they were uncertain on whether or not plenty of new technology was being utilized in BVCs in Malaysia. Despite this, they all agreed that there is no sufficient investment in developing technology in Malaysia and that government needs to play a greater role in creating incentives and putting forth initiatives to develop new technology for use in the biomass sector. They all also unanimously agree that the development of such technologies is essential in ensuring BVCs are implemented sustainably and in an environmentally friendly manner.

Interestingly, when asked if the technology used in Malaysia is comparable to technology used in other countries producing and processing similar biomass feedstock, 46.6% agreed. This indicates that the issue of lack of new technology being used and developed for more sustainable

BVCs is not just a problem locally, but also a major challenge in many other countries especially those within the region

Part 5: Role of Government in Malaysian Biomass Industry

The percentage of responses in Part 5 for each question can be observed in Figure 6.



	1	2	3	4	5
S. Agree	0	0	0	13.3	6.7
Agree	6.7	13.3	13.3	13.3	0
Uncertain	60	33.3	40	33.3	53.3
Disagree	13.3	26.7	13.3	20	13.3
S. Disagree	20	26.7	33.3	20	26.7

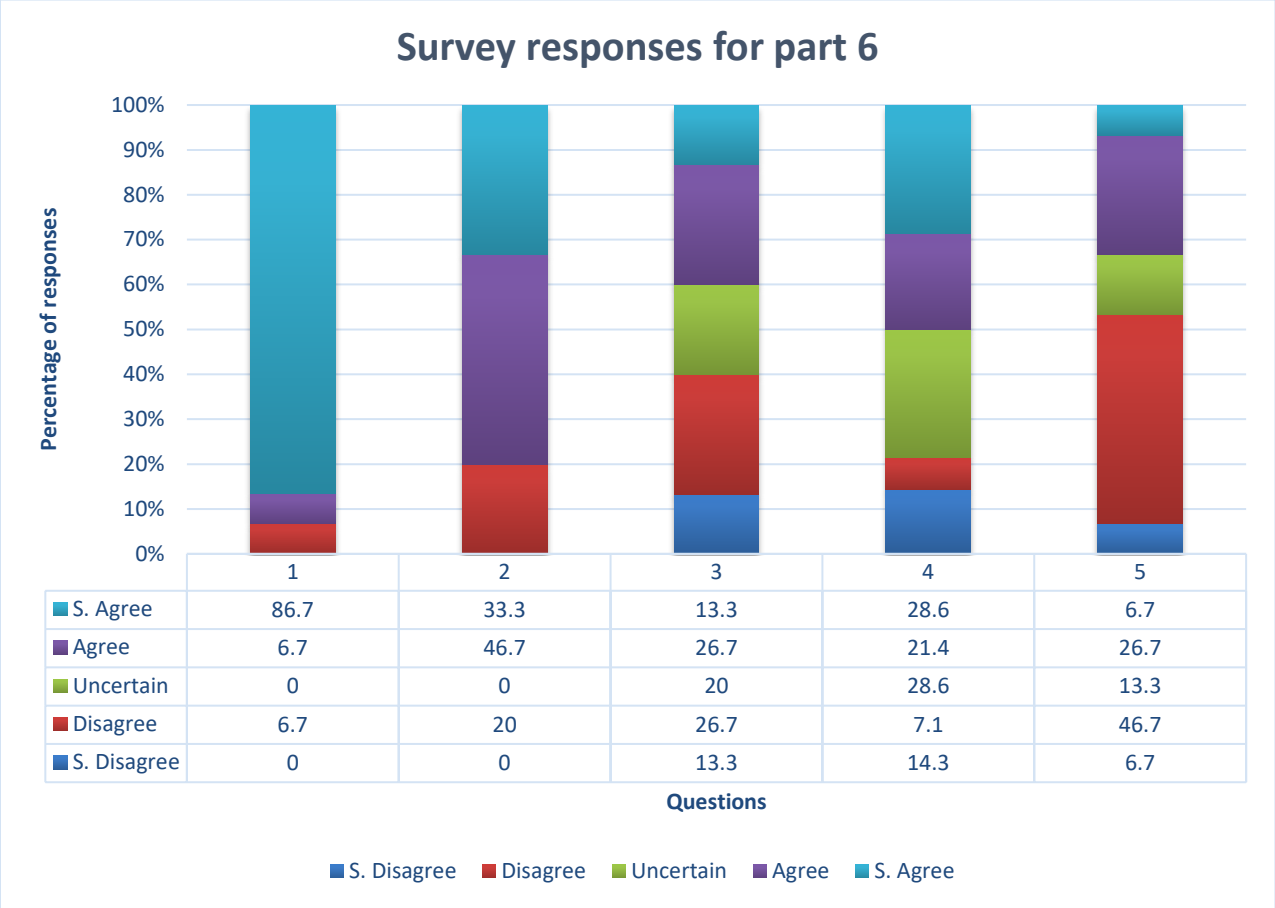
Figure 6: Responses for part 5 of survey

Government Involvement in Sustainable Optimization of BVCs

It was found that a majority of respondents were uncertain if current government efforts were sufficient or that more could be done on their part. They were also uncertain if the government had played a significant role in the growth of biomass sector within the past decade. However, most respondents agreed that at least when it comes to creating awareness of the environmental harms of unsustainable BVCs and investment in the sector, there is still some more room for improvement by the government. 53.4% also agreed that government ministries and agencies do not keep track of existing BVCs and monitor their impacts. This shows us that direct involvement by this entity within the biomass industry is still limited and should have better engagement and cooperation with industry stakeholders.

Part 6: Role of Private Sector in Biomass Industry

The percentage of responses in Part 6 for each question can be observed in Figure 7.



	1	2	3	4	5
S. Agree	86.7	33.3	13.3	28.6	6.7
Agree	6.7	46.7	26.7	21.4	26.7
Uncertain	0	0	20	28.6	13.3
Disagree	6.7	20	26.7	7.1	46.7
S. Disagree	0	0	13.3	14.3	6.7

Figure 7: Responses for part 6 of survey

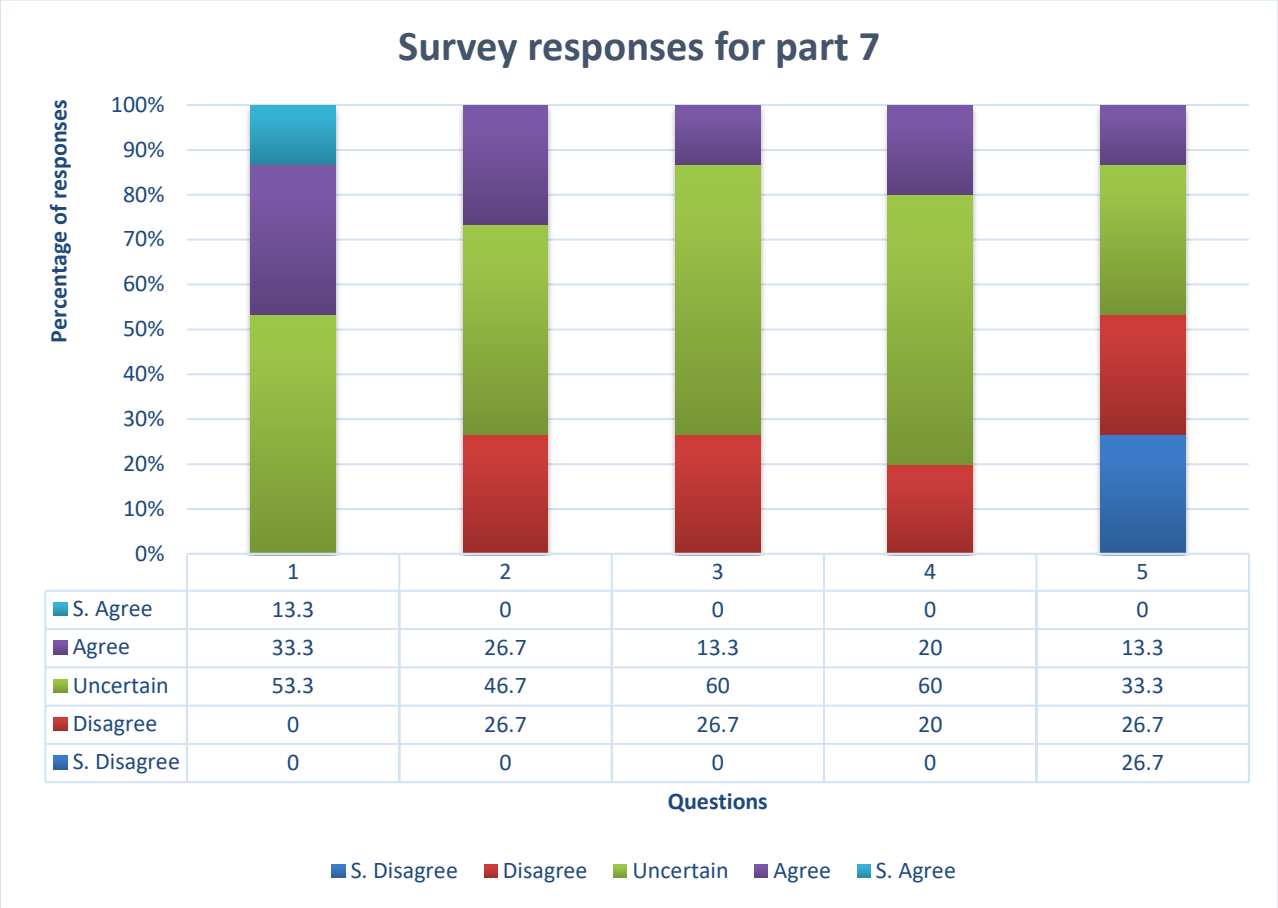
Private Sector Involvement in Sustainable Optimization of BVCs

It was found that the respondents all agree that private agencies and organizations play an important role in aiding the government to develop the biomass industry in Malaysia. 80% of respondents also agreed that currently the private sector provides many incentives and opportunities for the development of sustainable BVCs. Additionally, 53.4% of respondents agree that the private sector regularly invests in research and development for new technology that is able to reduce environmental impacts of existing BVCs. However, this may be limited to mostly the private organizations and not necessarily the privately operating biomass companies. This is determined as when asked if private companies were unconcerned about the environmental damage resulting from unsustainable BVCs, the results were split.

Other than that, 50% of respondents believe that biomass producers and processing plants are incentivized to implement more environmentally conscious practices in their BVCs. The results here prove to be inconclusive because another 50% disagreed or were uncertain on the matter. But if we take the results on a simple majority, we know that some incentives exist possibly from government efforts or initiatives. However, the efficacy of these incentives in creating more sustainable practices in BVCs is not known.

Part 7: Policies Related to Biomass Industry in Malaysia

The percentage of responses in Part 7 for each question can be observed in Figure 8.



	1	2	3	4	5
S. Agree	13.3	0	0	0	0
Agree	33.3	26.7	13.3	20	13.3
Uncertain	53.3	46.7	60	60	33.3
Disagree	0	26.7	26.7	20	26.7
S. Disagree	0	0	0	0	26.7

Figure 8: Responses for part 7 of survey

Policy Impact and Efficacy on BVCs

Based on the data collected, we can note that according to 53.4% of stakeholders, the existing environmental policies are not sufficient in ensuring sustainable BVC implementation. They believe that the policies require some revisions and updates to ensure they can effectively monitor and uphold environmental standards on existing BVCs being carried out.

Despite this, 53.3% of respondents were uncertain if policies enacted by the government have a significant enough effect in ensuring BVC related practices are in line with environmental regulations. 46.6% of respondents on the other hand, believed that policies were useful and necessary to deter unsustainable practices in the industry.

SPSS Results

Pearson correlation

The Pearson correlation matrix is shown in Table 3. Based on Table 3, we can observe that the role of private institutions (X3) shows the highest correlation at 0.410 followed by policies (X4) at 0.144, role of government (X2) at -0.005 and technology (X1) at -0.144. This tells us that based on the respondents surveyed, the sustainable implementation of biomass value chains in Malaysia can be improved most efficiently by encouraging a greater responsibility and having better policies on part of the private sector.

Table 3: Pearson correlation for identified dependent and independent variables

Variable	Y	X_1	X_2	X_3	X_4
Y	1	-0.144	-0.005	0.410	-0.008
X_1	-0.144	1	0.329	0.706	0.427
X_2	-0.005	0.329	1	0.315	0.411
X_3	0.410	0.706	0.315	1	0.223
X_4	-0.008	0.427	0.411	0.223	1

Model Summary

The Model Summary is shown in Table 4. From this, we note that the correlation coefficient, R=0.759. This value tells us about the correlation between the dependent variable and all the independent variables in the study. On the other hand, based on the R-square value, we know that 57.5% of the dependent variable can be explained by the variations in the independent variables.

$$y = \beta_0 + \beta_1 \cdot x_1 + \beta_2 \cdot x_2 + \beta_3 \cdot x_3 + \varepsilon \quad (1)$$

Table 4: Model summary

Model	R	R^2	Adjusted R^2	Std. Error of Estimate
1	0.759	-0.575	0.405	0.37219

The multifactorial regression model is shown in Table 5. the independent variable, X3 in the model is statistically significant (Sig. < 0.05). Additionally, the positive values on the beta coefficients confirms the convergent effect while the negative values indicate a divergent effect. As can be observed, the significance in values obtained do not pass the p-test as all except the X3 value showed significance greater than 0.05. This indicates that variables X1, X2 and X4 may not play a significant enough role in explaining the independent variable. Thus, the null hypothesis for these variables may have to be rejected except for that concerning variable X3.

Table 5: Multifactorial regression model

Model		Unstandardized Coefficient		Standardized Coefficients Beta	t	Significance
		B	Std. Error			
1	(constant)	2.392	0.806		2.968	0.014
	X_1	-0.823	0.274	-0.951	-3.007	0.130
	X_2	-0.710	0.144	-0.115	-0.493	0.633
	X_3	0.793	0.220	1.072	3.601	0.005
	X_4	0.233	0.275	0.207	0.849	0.416

It should also be noted that the sample size of this study is relatively small as only a total of 15 respondents had participated. Thus, this may have had an impact on the data analysis done and may explain the low significance and Pearson correlation values obtained.

We observed that variable, X3 which represents the role of private sector is the only statistically significant variable obtained through SPSS analysis. This tells us two things. It tells us that most of the respondents felt that the private sector plays a crucial role and are an important enabler for development of the local biomass sector in terms of environmental sustainability. It also tells us that most respondents believed that currently the private sector has been actively involved and is significantly contributing towards the implementation of BVCs in line with EFEW.

The current role of private sector can be seen through its many efforts in reducing carbon footprint within its BVCs and commitment towards sustainable practices. From a technical standpoint, private companies have started embracing process integration tools (PI) such as pinch analysis and mathematical modelling to reduce the carbon footprint produced during oil palm biomass processing. Other than that, implementations of good engineering practices and significant investment in new technology to address environmental concerns such as reduction of steam, electricity, and fuel consumption during processing. Notably, the private sector's active involvement in research and development of 'waste to wealth' conversion such as biogas capture, biochar and biofertilizers from biomass processing waste has also been an important enabler of EFEW nexus in BVCs.

When it comes to the other variables analyzed, the lack of significance obtained tells us that according to the respondents, there has not been sufficient contribution on the part of government, policies, and new technology to sustainably optimize existing BVCs. In other words, this means that the lack of active government involvement, effective policy and technology are disablers of EFEW nexus in BVCs. This tells us that improvements have to be made with regards to these factors in order to ensure local BVC implementation can reach optimum sustainability.

Conclusion

Biomass possesses great potential for development into a viable energy source environmentally friendly value-added product. However, existing biomass value chains often are too complex and inefficient in meeting performance requirements and are found to be detrimental to the environment. Thus, optimized biomass value chains that are in line with the energy-food-water-environment (EFEW) nexus is required to control the and minimize the impacts towards the environment. The EFEW nexus allows us to gauge this by providing meaningful insight on the interactions that BVCs have on our surrounding food, energy, and water resources. Understanding these interactions will allows the fulfilment of the set research objective, which is to identify and assess the enablers and disablers of EFEW in BVC. Through analysis of the survey questionnaire prepared we can come up with several findings that allowed us to understand the challenges and opportunities involved for implementation of EFEW nexus in BVC. Through analysis of results, we reflect insight into the perception of stakeholders on biomass value chains and its possible negative impacts on the environment. We were also able to gauge the challenges involved which allowed us to understand the enablers and disablers sustainable BVC implementation in line with EFEW nexus. From this, we find that most challenging part of BVC implementation according to the respondents is the issue of transportation and logistics, followed closely by cost, policy enforcement, technology, and inconsistency in supply. Analysis of SPSS survey results clearly visualize the relationship between the dependent variable, which is the implementation of sustainable BVC and the independent variables. From the Pearson correlations, we found that X3 (referring to role of private sector) showed the highest correlation and was the only statistically significant variable obtained based on the model. Thus, we are able to determine that role of private sector has significantly contributed to optimizing BVCs, making it an enabler, while the insufficiencies of government role, policies and technology have not significantly contributed towards this, making it a disabler.

Acknowledgements
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