Journal of Surveying, Construction and Property (JSCP) **Volume 12, 2021 Issue 1**
ISSN: 1985-7527

RECYCLING OF CONSTRUCTION TIMBER WASTE TO ENERGY: A CASE STUDY IN MALAYSIA

Ng Yee Lin[1], Zahiruddin Fitri bin Abu Hassan[2]*, Imaduddin bin Abdul Halim[3]

[1,2,3]Centre for Building, Construction and Tropical Architecture (BuCTA), Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia

E-mail: *zahiruddin@um.edu.my

ABSTRACT

In recent years, there are increasing environmental issue due to the construction waste especially in Malaysia. Timber waste has covered two thirds percentage of the construction waste. Hence, potential on construction timber waste recycling to energy specifically in Malaysia under the states with solid waste managed by Solid Waste and Public Cleansing Corporation (SWCorp) is being studied. The research objectives are to investigate the improvement factors and current practices by the timber waste contractors in Malaysia. The study was conducted using a mixed method research approach to SWCorp officer, timber waste contractors and timber recycling center representatives to discover in depth the timber waste recycling to energy in Malaysia. The findings for the improvement factors from the current practices are authority enforcement, revenue from selling the timber waste, limitation of landfill spaces and public awareness. It is targeted that the research findings and recommendations will be useful for the waste authority, timber waste contractors and the public to reduce the timber waste being sent to landfill.

Keywords: Construction Waste, Wood Recycling, Timber Waste to Energy

1. INTRODUCTION

Construction Industry Development Board (CIDB) estimates that the construction industry account for more than 30 per cent of the total waste generated in Malaysia (CIDB Malaysia, 2015). The study has shown that a significant of almost one-third of the waste generated is coming from the construction sector. Many large cities around the world are facing a worrying environmental problem due to the increase of construction waste including Malaysia. Malaysia as a developing country and hence minimizing the construction wastes has become a public concern and one of the pressing issue according to Begum, Siwar, Pereira, and Jaafar (2006).

Six types of waste on 30 construction sites are identified by a research conducted by Faridah et al. (2004) as cited in Nagapan, Abdul Rahman, and Asmi (2012) known as wood (69.10%), concrete (12.32%), metal (9.62%), bricks (6.54%), plastics (0.43%) and other waste (2%). This study has been narrowed down to the construction timber waste because about 25% of the timber used annually around the world is consumed by the construction of buildings according to the Worldwatch Institute as mentioned in Dimoudi and Tompa (2008). Combining the outcomes from both previous researches, it is obvious that the wood waste generated from the construction site covers a significant impact on the waste composition in the construction site. Therefore, this research must discover the improvement factors of timber waste recycling in Malaysia to close the research gap for the optimization of the timber waste in the construction site.

The management of solid waste is the largest environmental issue in Malaysia. This is due to its dependency of landfilling as the main disposal method in managing this consecutive increase of solid waste generation every year which has led to the ambiguity in the future of the solid waste management although there are other ways of administering and reducing solid waste according to Moh and Abd Manaf (2016). The conventional method of managing the timber waste in the site is in fact unsustainable. Wang, Chen, Tsang, Poon, and Shih (2016)

stated that a significant environmental burdens and economic wastage occurred because of the disposal of contaminated wood formwork from the construction sites to the landfill. Since the common practices are throwing the timber waste to the landfill, factors of improving the recycling of timber waste must be discovered.

As mentioned, more than 30% of the solid waste in Malaysia was generated by the construction industry (CIDB Malaysia, 2015) and wood waste was the major waste in the construction site. Thus, there is a need to discover the potential of recycling timber waste in order to find alternatives to dispose of the timber waste in Malaysia. Since accurate decision making in solid waste management strategy required the knowledge in solid waste generation and composition as mentioned by Hamid, Samah, and Ishak (2015). The main aim of this article is to investigate the improvement factors and current practices in the construction industry timber waste recycling specifically in Malaysia under the states with solid waste managed by Solid Waste and Public Cleansing Corporation (SWCorp). This is because SWCorp is the implementer of Solid Waste and Public Cleansing Management Act 672. According to Agamuthu, Hamid, and Khidzir (2009) the Malaysian government has created this Act 672 which improves and ensures high quality services in solid waste management.

2. LITERATURE REVIEW

The timber waste has the potential to be recycled as combustion material to produce renewable energy. Before year 2007, Malaysia has been dependent on the natural gas which contributed about 68% as the fuel for electricity generation in Peninsular Malaysia as announced by Tenaga Nasional Berhad (TNB) and reported in The Sun (2017). Upon realizing the risk of over-dependence on the natural gas that will post the power outrage during gas supply disruption, this has shown a shift of dependency to 51% coal or fossil fuel to generate electricity in year 2017. Besides, liquefied natural gas (LNG) was also introduced. Timber waste which is a renewable organic material has been provided about 10% of energy consumption in Germany according to Weisleder, Nasseri, and Elbstr (2006). Thus, Malaysian could adopt the same strategy as the other country in order to convert the timber waste into another form which is the electricity or renewable energy.

Prof. Dr. P. Agamuthu has mentioned that the thermal treatment is the best waste to energy option for Malaysia (Menon, 2017). About 20 years ago, flue gas emission that produced dioxin and furan has deterred the thermal energy production using waste. However, he explained that with the technologies have advanced that there will be no emission of dioxin and furan from thermal treatment (Menon, 2017). Besides gas emission, another additional product from Waste to Energy (WTE) is the ash residue. The ash residue from WTE amount to 25% of incoming fuel by weight or 10 to 15% by volume according to Merritt (2002). He further explained that the ash has two major components known as bottom ash and fly residue. Many European facilities and some American facilities keep it separate from bottom ash and specifically treat it to permanently capture or neutralize those toxins. That fly ash only represents about 1% of the original fuel input. It is typically landfilled as there are no commercially viable conversion technologies available.

WTE plant is different from existing mini incinerators in Malaysia, which is in Langkawi, Cameron Highland, Tioman and Pangkor. However, only Tioman is still operational. National Solid Waste Management Department (JPSPN) director-general Ismail Mokhtar said having WTE plant is common in other countries. Malaysia is considered behind schedule in building the WTE plant as most of the developing countries already have it. He further explained that the project of WTE plant cost between RM700million to RM900 million is to be built on 1.62 hectar of land in Taman Beringin Kuala Lumpur next to the current transfer station. It is from the partnership between government and private corporations. The project is in the final tendering stage and the project requires 3 years to be built. An average 2,700 tonnes of waste has been sent to the transfer station each day which has exceeded its capacity of 1,700 tonnes per day at Jinjang Selatan. For every 1,000 tonnes of waste burned, 25 to 30 megawatts of electricity per hour is generated to cater 57,000 houses (Lim, 2017).

Landfilling the construction waste especially the timber waste is not recommended. This is because 50% methane (CH_4) gas and 50% carbon dioxide (CO_2) gas were emitted in landfills (Thorneloe, Roquetta, Pacey, & Bottero, 2000). When waste decomposes anaerobically, Gupta and Gagnon-Lebrun (2002) mentioned that methane is generated and carbon dioxide is generated when waste decomposes aerobically. Methane gas has a global warming potential 21 times stronger over a 100 year period than carbon dioxide gas (Kruger, Beer, Wainberg, & Huqinh, 2000). WTE is a better choice of ending the timber waste because Ackerman (2002) has given an example of burning papers which is made out of wood that has zero net emissions by burning it to replace the fossil fuel which is not renewable. Besides, fossil fuel has the potential to produce acid rain results from sulphur dioxide and nitrous oxides emitted from the fuels (Oladimeiji, Kumar, Parekh, & Bhala, 2002). Bouwmans (2002) agreed that a large amount of primary fuel can be saved via thermal waste treatment.

3. METHODOLOGY

Research methodology chronological flow chart is illustrated in Figure 1. Data collection in Stage 1 starts with an exploratory interview with the Solid Waste and Public Cleansing Corporation (SWCorp) assistant director of Technology & Research division to understand the management of the construction solid waste in Malaysia. Secondly, the quantitative approach has been used via email and tele-conversation survey from the list provided by SWCorp to discover the factors that encourage timber waste being diverted from landfill in Malaysia. Finally, the data collection ends with site observation and interviewing the timber waste contractors, timber recycling center and WTE plant manager to deeply understand the improvement factors and current practices in Malaysia. Davies and Beaumont (2011) supported that triangulation provides good case studies as it covers different research tools to increase the validity such as surveys, interviews and documentation review as conducted in this research.

The following stage is the analysis of the data collected from the SWCorp and detailed information from the timber waste contractors, timber recycling center and WTE plant in Malaysia. A further semi-structured interview has been conducted to these target respondents to compile their knowledge and experience. In a case study research, particular understanding and insight will be obtained (Faquhar, 2012).

The final stage is the summary of findings and provision of recommendations to enhance the findings

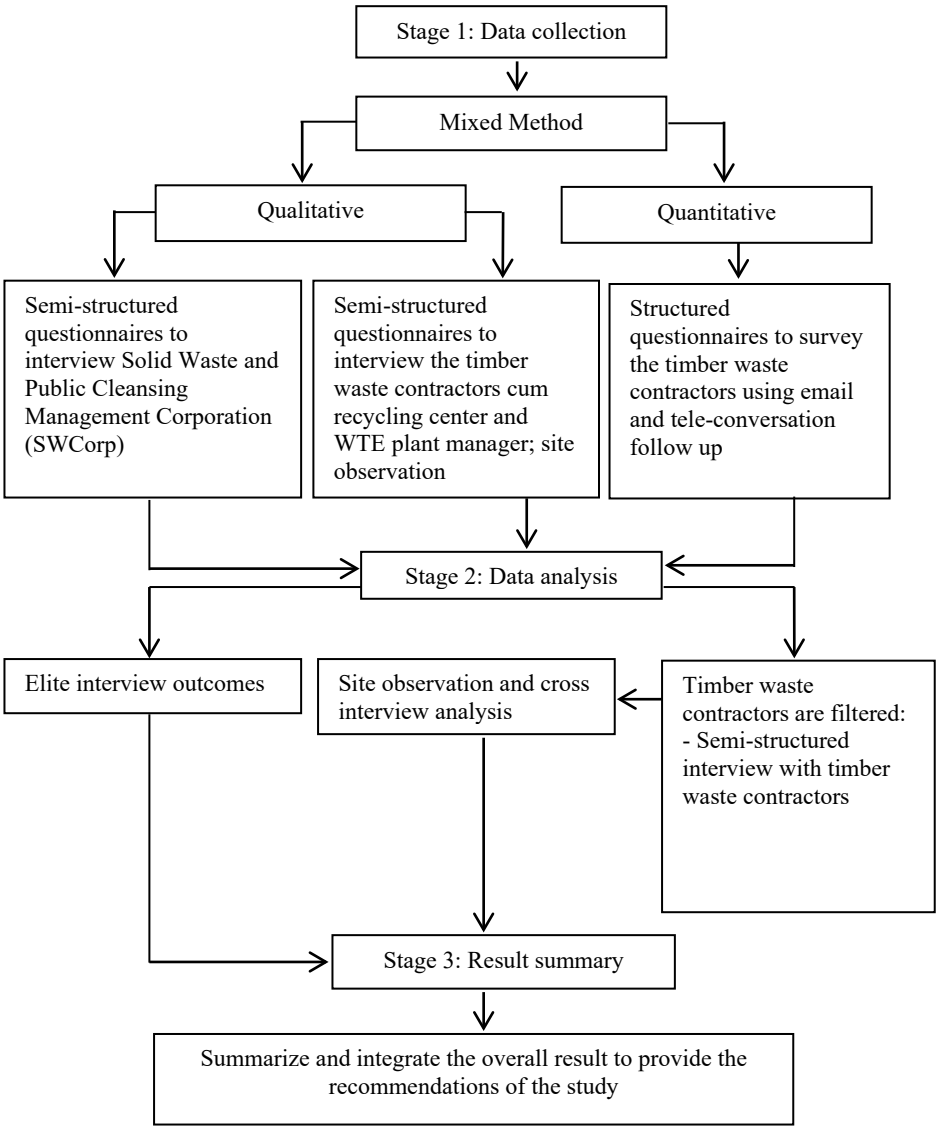

Figure 1: Research methodology chronological flowchart.

3.1 Exploratory interview

The purpose to do this exploratory interview with SWCorp is to gain insights into the operation currently done by them to manage the construction waste in Malaysia and the semi-structured interview has reaffirmed on the available population of the timber waste contractors in Malaysia. The interview questionnaire consists of three parts namely Part A, B and C. Part A starts with the basic introduction of the demographic of the respondent. This includes the current designation, highest level of educational qualification, years of working experience and the company information. Part B involves the general questions about construction waste management. This part consists of the understanding on the role of the organization and action taken against the illegal waste problem. Open ended question has been used throughout this semi-structural interview as this type of questions will give the respondent an opportunity to give their full perspective based on their experience according to Fink (2013). Part C is the main list of questions about the timber waste management specifically. This part is responsible to gather the core data for this research. The possibility to recycle the timber waste is being explored and the opinions and experiences on the practices of timber waste management in the organization have been captured.

3.2 Structured survey sampling

The number of timber waste contractors remains the same as in the SWCorp website which is 185 contractors as published in year 2015. Figure 2 has shown the sampling process. Timber waste contractors working with the timber waste line have been surveyed using closed questionnaires to measure the choice of process to manage the timber waste starting from receiving the waste and their perception on recycling used timber from the construction site.

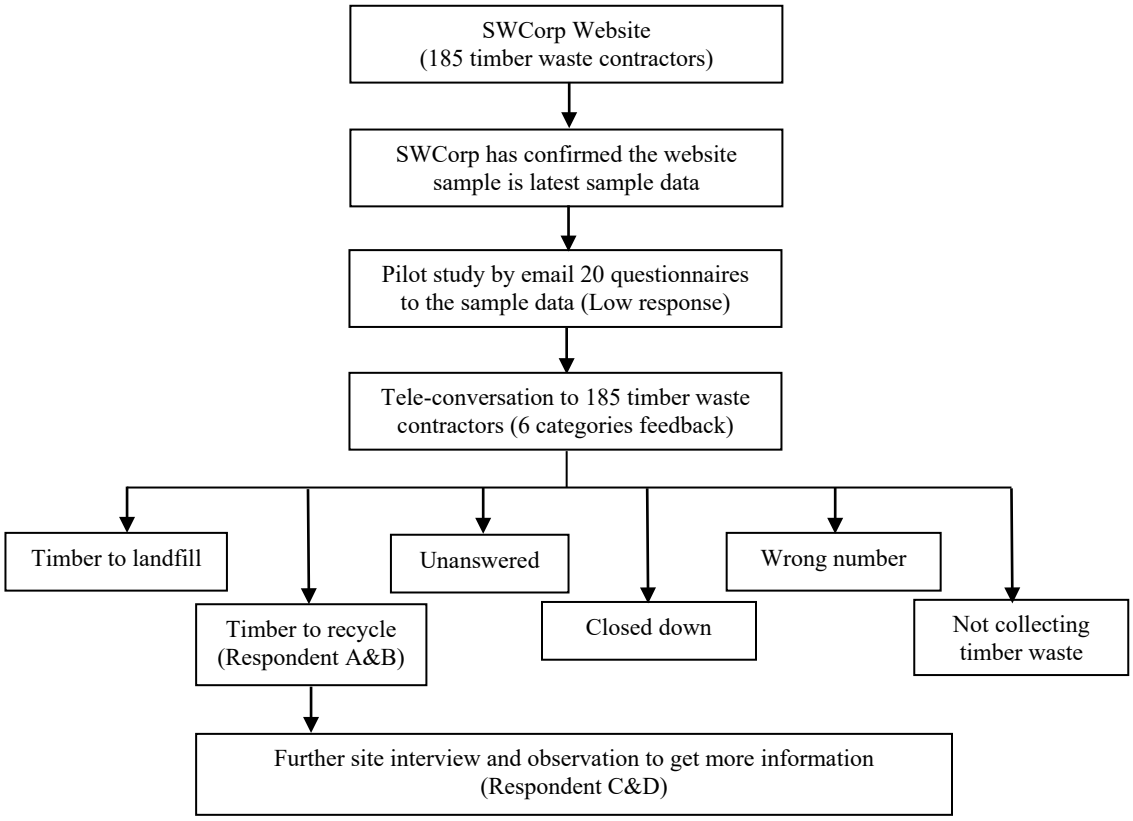

Figure 2: Research structured survey sampling.

For the first round of questionnaires survey, twenty pilot surveys have been distributed to a twenty randomly picked samples to test the feasibility of the questionnaires. Low response received and the questionnaires have been surveyed using tele-conversation to all the targeted population of the timber waste contractors as listed in SWCorp website. The sample size for this research is 127 timber waste contractors as the known population is under the 190 category as described in the sample size determination from a given population (Krejcie & Morgan, 1970). However, the researcher has contacted all the 185 contractors and six categories has been gathered in the

tele-conversation survey.

3.3 Site interview and observation

Site interview and observation has been conducted to capture the live processes of recycling the timber waste in the timber recycling factory. This semi-structured interview questions are used as the face to face interview with the timber waste contractor cum recycling factory director and WTE plant manager. The results of the interview have been tabulated.

4. RESULTS

The results cover the exploratory interview with 1 SWCorp officer, 185 timber waste contractors with structured survey questionnaires (2 answered the full survey questionnaires) and the rest being filtered based on suitability of sample, a further site interview to another 2 timber waste contractors and observation on their timber recycling site. The summary of research findings is illustrated in Table 1.

Table 1: Summary of research findings

Exploratory interview with SWCorp	- Reaffirmed the 185 list of timber waste contractor in the website. - SWCorp officer has supported that the timber waste could be recycled. - The waste could be recycled into particleboard, paper, animal bedding, landscape application, and erosion control. - As for the fuel production, it is possible but depended on the volume of the timber waste and technology wise because timber waste is very high energy, the factory may consider it according to the officer. - Besides, another problem discouraging recycling of timber waste is due to the low market rate for purchasing of timber waste.
Structured survey questionnaires	- Categorized into 6 categories. - Filtered the target respondents of the research who are the existing timber waste contractors. - Respondent A and B answered the full structured survey questionnaires through tele-conversation.
Site interview and observation	- Site interview has been conducted to get in depth information from the timber waste contractors. - Respondent C & D has shared their experience and knowledge in the timber recycling management. - Site photos captured the timber waste recycling process.
Improvement factors	- Authority enforcement. - Revenue from selling the timber waste. - Limitation of landfill spaces. - Public awareness.
Current practices	- 61% of the timber waste contractor sent timber waste to landfill and 39% of the timber waste contractors sent to recycling center.

4.1 Exploratory interview with SWCorp

Semi-structured interview with SWCorp has reaffirmed on the available population of the timber waste contractors in Malaysia which is 185 companies. SWCorp has mentioned that the illegal dumping of construction waste will subject to the minimum fine of RM10,000 or 6 months jail and maximum fine of RM100,000 or 5 years jail term. SWCorp randomly select the construction project and check on documentation of the location of the dumping site. There have been cases of illegal dumping being caught by SWCorp. Those contractors need to be registered or notice will be issued to them. The importance of registered waste contractors is because they will not violate the rules.

SWCorp holds a major role in monitoring the waste management at the construction site. Technical teams from SWCorp are deployed to the 7 states in which SWCorp has the authorization. These technical personnel will monitor and go to the entire site to ensure the management at the site follows all the guideline. Thus, several approaches with the local authorities such as in Wilayah Persekutuan under Dewan Bandaraya Kuala Lumpur

(DBKL) have successfully placed the SWCorp's guideline as a mandatory compliance in order to approve the development order (DO) of the project. It has proved successful when all the developers are complying with the guideline for approval of their project.

The representative from SWCorp has listed three types of construction stages. For new construction, it starts from bare land. The second is the renovation and the third is demolition. Based on these three stages, the waste composition is different. The new construction has a lot of timber waste for concreting such as formwork. For demolition, there is a lot of concrete waste and for renovation, the concrete and timber waste are quite balance but not much compared to new construction. Besides, an example of recycling the timber waste is given by the representative from SWCorp. There is a project in Malacca whereby the waste contractor does not know the way to dispose the timber formwork other than landfill it. However, SWCorp has suggested that the formwork waste to be brought to a brick manufacturing company because wood is very high energy material. This brick manufacturers need wood to be burnt and they do not consider the quality of the wood because timber formwork still has the concrete residue attached to it.

SWCorp officer has supported that the timber waste could be recycled. The waste could be recycled into particleboard, paper, animal bedding, landscape application, and erosion control. As for the fuel production, it is possible but depended on the volume of the timber waste and technology wise because timber waste is very high energy, the factory may consider it according to the officer. Besides, another problem discouraging recycling of timber waste is due to the low market rate for purchasing of timber waste.

4.2 Structured survey questionnaires

There is a total of 185 companies expected to be involved in the construction timber waste collection as registered with SWCorp updated on the website since year 2015. Telephone survey is chosen as this method is the fastest method to gather the information from the respective respondents. Besides, this method saves on the time and cost used for travelling to the respective companies involved. From the telephone survey, the result is that 36 of the companies stated that they collected the timber waste from the construction site while 85 companies (closed company, wrong number and contractor not doing timber waste) informed that they are not involved in the collection of timber waste and 64 phone calls are unanswered due to voicemail, not answering, engaged tone and number not provided in the SWCorp list. This telephone survey has filtered the actual construction timber waste contractors that are still collecting timber waste as of year 2018.

Table 2: Result from tele-conversation survey.

Category	Number of contractors	Percentage (%)
Timber waste sent to landfill *	22	12
Timber waste sent for recycling *	14	7
Unanswered phone number †	64	35
Closed company	3	2
Wrong number	47	25
Contractor not doing timber waste	35	19
Total	185	100

* Actual targeted respondents
† Unanswered phone number include voicemail, no answer, engaged and number not provided

Table 2 shown the total number of 185 timber waste contractors which is the result of filtering some of the repeated companies in various states in Malaysia registered with SWCorp. SWCorp has mentioned during the interview that the list updated on the website in 2015 was obtained from the Local Authorities. The filtering is vital because some companies can register themselves in various states. For an instance, a contractor from Kuala Lumpur can apply their license from Kuala Lumpur and at the same time apply from the other states such as Johor, Malacca etc. This is because the contractors are providing the collection and transportation services of the construction waste. Logistic benefits the waste contractors because it is a type of mobilization services. Mobilization allows the contractors' company listed in various states in Malaysia. However, the same company with the same address and telephone number will not provide a different response although it provides services in different states. Hence, the filtering is completed to obtain the total number of timber waste contractors. Besides, the waste contractors can apply the category of waste that they are collecting. The waste category includes the concrete, scrap metal, timber, site clearing, ceramic, plastic, soil and sand.

This survey result has shown that not all the registered contractors with SWCorp and selected timber waste as one of the categories of waste to be collected do collect timber waste at the end. However, this study has been focusing on the timber recycling. Hence, the targeted respondents must collect the timber waste in construction site instead of the other category of waste. In this research, the actual timber waste contractors identified are comprised of 19% whereby 12% are sending the timber waste collected from the construction site to the landfill directly and the other 7% sent the timber waste for recycling.

Based on the 36 number of actual timber waste contractors, 14 of them admitted collecting the timber waste and sent for recycling. The rest of the 22 waste contractors said they sent to landfill directly. The feedback given was because the recycling yard is far away, and they do not have collection center to keep the timber waste. There is also one of the timber waste contractors who believe that timber is already end user and could not be reused or recycled. Besides, there was no demand in the market to receive the timber waste as mentioned by a waste contractor from Johor. While another timber waste contractor in Kedah said that timber waste recycling center is not available in Kedah. Thus, sending the timber waste from the construction site directly to landfill were their common practices.

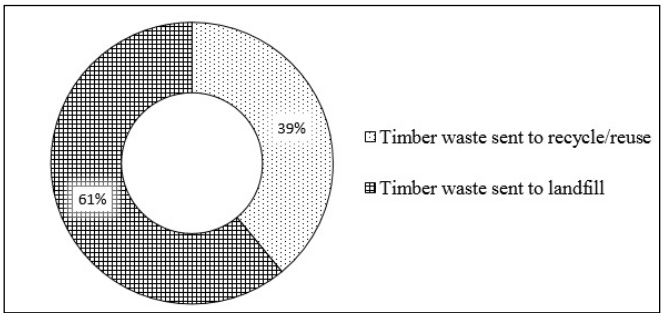

Figure 3: Percentage of timber waste reutilization, recycling and landfill based on number of actual timber waste contractors.

Figure 3 shows the percentage calculated from the number of actual timber waste contractors who reutilize, recycle and landfill the timber waste collected from the construction site. Most of the contractors' common practices are sending the timber waste to the landfill which represented 61% of the total 36 number of actual timber waste contractors. This result has supported the research by Moh and Abd Manaf (2016) that has mentioned Malaysian is depending heavily on landfilling in Malaysia. Meanwhile the figure also shown 39% or 14 contractors out of the 36 number of actual timber waste contractors have recycled or reused the timber waste from the construction site.

4.3 Site interview and observation

A total of four respondents are obtained in this research as representatives for the timber waste contractors who are considered green contractor because they take the extra effort to reuse and recycle the timber waste. The list of respondents with the demographic is summarised in Table 3.

Table 3: Respondent demographic.

Respondent	Position	Years of experience	Educational level
A	Managing Director	21-25	Secondary
B	Director	11-15	Primary
C	Director	30	Bachelor's degree
D	Plant Manager	20	Bachelor's degree

Table 3 shows a comparison of different respondents which represented the timber waste industry in Malaysia. Respondent A has 21 to 25 years of working experience in the timber waste line but only studied until secondary education. While respondent B has studied until primary education and has 11 to 15 years of working experiences. Respondent C has a high educational level until bachelor's degree and has 30 years of working experiences. While respondent D has 20 working years of experience and a bachelor's degree holder. However, the research with this different background respondent has shown that they have expressed the similar view, or this

research has reached a saturation of data on the option to manage the timber waste in Malaysia. Hence, the research has reached reliability when four of the contractors surveyed and interviewed have informed that the timber waste is being sent to the Waste to Energy plant to generate energy. Reliability is the results yield is consistent in repeated ways according to Davies and Beaumont (2011).

A cross-interview analysis is shown in Table 4 to compare the responses from the four respondents from different company background. The result has shown that respondent C who had a higher education background and working experiences tend to find more options to reutilize and recycle the timber waste. Respondent A and B are with the pure waste contractor background. The waste contractor responsibility includes collecting the timber waste and sending the waste either for reuse, recycling or landfill. While respondent C and D hold the waste contractor position at the same time has a timber recycling yard and plant respectively. The comparison has shown that those with the higher education level seem to find more alternative methods in managing the timber waste.

4.3.1 Type of construction waste collected

Respondent A has informed that his company collected scrap metal, timber waste and soil waste. The respondent has not been documenting it in paperwork, hence the respondent unable to provide the tonnage of waste collected. Respondent B has given the estimated amount of scrap metal collected about 200 tons per year, timber waste collected about 1,800 tons per year and 60 tons per year of plastic waste collected. Respondent C has mentioned that his company only collecting timber waste and does not collect other waste. Respondent C unable to provide the estimated amount of timber waste collected because he pointed out that they do not have a rigid scale. However, based on his experience, about 3 tons of timber waste can be collected via a 20 feet construction bin. Respondent B and Respondent C have mentioned that their timber waste is being sent to waste to energy plant managed by Respondent D.

Respondent D who worked as plant manager for a power plant which converts timber waste into green energy has pointed out that 3600 tons of timber waste came from saw mill and 24000 tons of municipal waste including construction timber waste were collected and sent to their plant as fuel annually. In addition, Respondent D has mentioned that there are four collection centers located at Bukit Rimau, Sungai Buloh, Rawang and Rasa. Each of the collection centers is about 1 acre in size. All the centers only collect timber waste to be sent for chipping and burning at the power plant located at Rasa.

Table 4: Cross interview analysis.

Questions of analysis	Respondent A	Respondent B	Respondent C	Respondent D
Type of construction waste collected	• Concrete waste • Timber waste • Soil waste	• Scrap metal • Timber waste • Plastic waste	• Only timber waste	• Only timber waste
Recycle timber waste	• Yes	• Yes	• Yes	• Yes
Estimated number of projects with timber waste collected: i) Highrise ii) Landed/low-rise iii) Infrastructure	 i) No record ii) No record iii) No record	 i) Zero ii) 1 to 10 projects iii) Zero	 i) 80% ii) 20% iii) Zero	 i) No record ii) No record iii) No record
Factors to improve recycling of timber waste	• Revenue	• Limitation to landfill spaces.	• Enforcement	• Awareness from the people.
Company's best practices on timber waste management	• WTE	• WTE	• Reuse as pallet and formwork and WTE	• WTE

4.3.2 Recycle timber waste

Table 4 has illustrated that all the four respondents have agreed that timber waste can be recycled. Respondent C has reused the timber waste as pallet and formwork. Other than the reusable timber, the rest of the timber waste is sent to the waste to energy factory. Respondent A has also agreed that timber waste is sold to the reusable energy factory to be burn for heating boilers. Respondent B on the other hand has mentioned that he used to have 7 machines that can grind the timber waste into woodchip and has a sellout value of RM180 per ton but due to not receiving enough volume of timber waste, respondent B ended up sending the timber waste to the recycling factory. This is also due to the high usage of electricity of about RM2000 per day for using the 200 horsepower machines to grind the timber waste. Respondent D has mentioned that all the timber waste that was sent to his plant was only mending for energy recovery. Previously, timber waste was sent for burning and thrown at dump site. So, it will be a landfill site. However, this timber still can be utilized to generate power. This waste will be wood fuel for boiler, produce steam and steam turbine to generate power 7 Megawatts per hour including housework. Respondent D said that the plant export 6 Megawatts per hour to the Tenaga Nasional Berhad (TNB).

4.3.3 Number of projects received timber waste

Respondent B received timber waste from landed projects in the range of 1 to 10 projects per year. Respondent C collected about 80% timber waste from the high-rise project and about 20% from the landed or low-rise project. Respondent A and Respondent D have mentioned that their company does not keep the records of the origin of the waste generated. As it is not their business on the origin of the wood. Based on their response, it can be summarized that the documentation or database system is not collated in Malaysia. However, none of the respondents received the timber waste from the infrastructure project. This is because there is an imbalance requirement for the IBS in Malaysia as the government has requirement on the public projects to use the IBS but the private projects are still reluctant to accept the system unless required by the authorities as mentioned by Kamar, Azman, and Nawi (2014). Normally, the infrastructure project utilize the IBS system because it is repetitive throughout the line for example the Light Rail Transit (LRT) which has a consistent shape and structure. This shows that there is still demand in the construction of building on this timber and hence it has become a waste after being used. Proper way to manage the timber waste after its service in the construction project is important as this research aims to find the improvement factors to optimize the recycling of timber waste generated from the site.

4.3.4 Factors improving recycling of timber waste

Respondent A stated that revenue is the factor that encourages timber recycling. This is because 98% of the timber waste collected is sold to the waste to energy plant, thus it brings revenue to Respondent A. Revenue is the source of income for all the business. Respondent B mentioned that limitation of landfill spaces as the most important factor. Landfill sites in Malaysia are always not enough despite the dominance of recyclable materials in the waste composition due to the minimal source separation for recycling on top of open and illegal dumping of waste as mentioned by Moh and Abd Manaf (2016).

Respondent C has stressed that enforcement is the factor that will improve the recycling of timber waste. Respondent C has given an example of project registered with the Green Building Index in Malaysia where the project must comply with the waste separation on site. If the waste is not segregate at the site, it will not end up at recycling yard, it will go directly to the landfill or dumpsite. Respondent C suggested making it compulsory that every construction project must recycle at the site. Respondent D also support that authority enforcement is the factor to improve the recycling of timber waste. This is because proper segregation at the site can save on the operation cost. According to Gritten (2007), waste which is incorrectly sorted in Finland can be returned to its last holder. This is a good move whereby the people will carefully sort their waste. Respondent D has also added that the awareness of the people is the most crucial effort to curb this waste of fuel. Malaysian must shift the perspective that timber waste can be converted to energy.

4.3.5 Current practices on timber waste management

All the four respondents have agreed that the best method on timber waste management is to send the timber waste from the construction site to the waste to energy factory. In fact, the fossil fuel is declining and conservation of those that once thought unusable is necessary as mentioned by Porteous (1981). The waste management hierarchy as mentioned by Fauziah and Agamuthu (2010) on the sustainable stages of proper waste management has started firstly with waste prevention, followed by waste reutilization, recycle and disposal. Since

the timber waste is a waste that is already generated at the construction site based on the usage especially in the building project, hence the recycling of the timber waste to energy is always better that sending the waste to the landfill. At least there is energy recovery for other consumers to use it instead of burning the fossil fuel. For example, Respondent D's energy plant has the wood fuel for boiler, produce steam and steam turbine to generate power of 7 Megawatts per hour including housework and able to export 6 Megawatts per hour to the Tenaga Nasional Berhad (TNB) power gridline. It is discovered that 25 megawatts of energy can power up to 57,000 houses according to Lim (2017). Hence, 6 megawatts of electricity can cater at least 13,680 houses using a direct mathematical conversion.

In the site observation, the timber waste from the construction site is being sent to the timber recycling center. The laborers will segregate the waste into mix timber and plywood. After sorting according to the reusability, the unusable timber waste such as those contaminated with oil or odd shapes timber waste is sent to the waste to energy factory to be chipped and burned to generate electricity as shown in Figure 4.

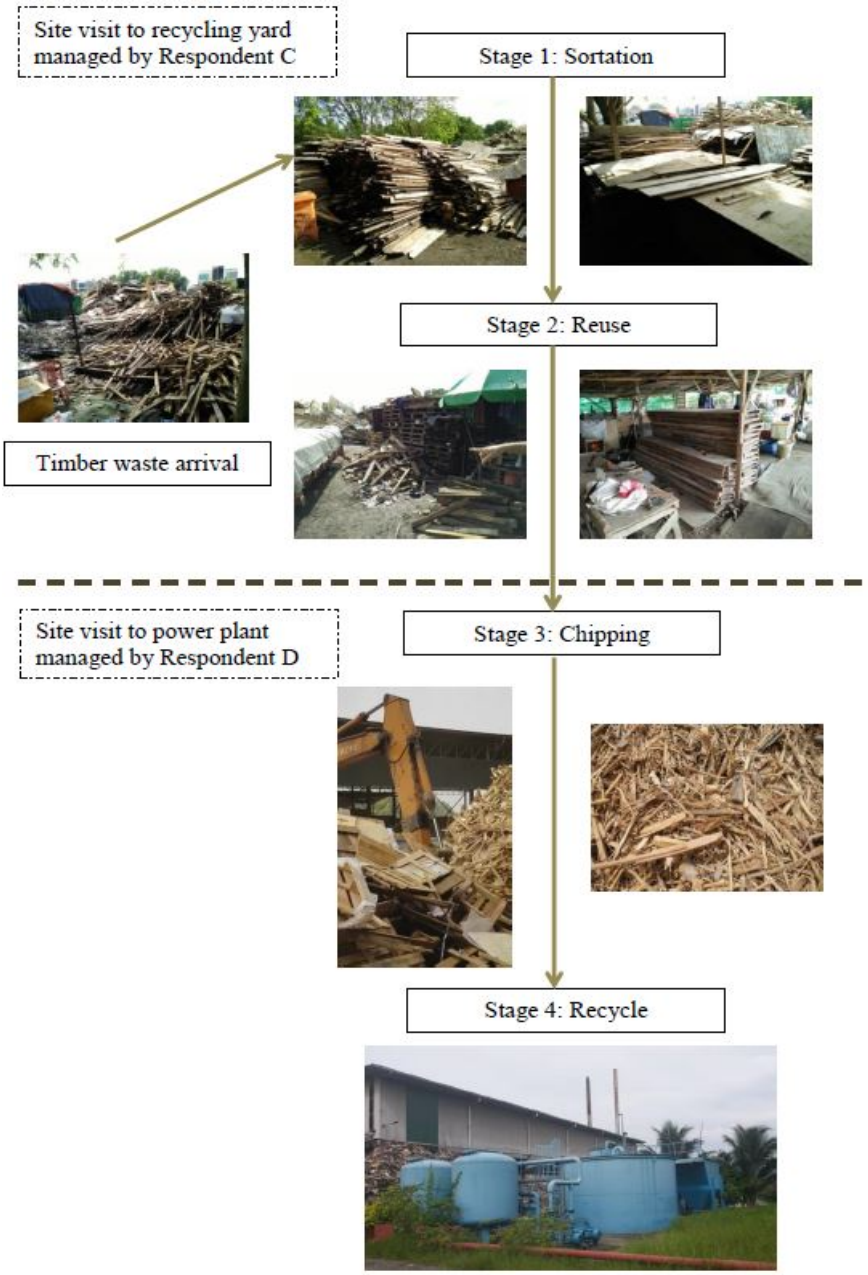

Figure 4: Recycling of timber waste in Malaysia.

5. DISCUSSION

SWCorp plays an important role in enforcing and implementing the Act 672. This Act 672 is created to manage the waste in Malaysia efficiently. After year 2011, the local authorities have given their power of managing the solid waste to SWCorp. This corporation has a list of registered waste contractors. By contacting the list of contractors provided, it is discovered that there are various methods to divert the construction timber waste from the limited landfill spaces in Malaysia. However, due to lack of awareness and limited enforcement on this timber waste, most of the timber waste ends up in the landfill.

Besides, the waste contractors are also facing difficulty in special space requirement for timber grinding which need to be built in the industrial land according to Malaysia structure plan. Logistic planning on the location of the timber collection yard and the project site shall be within the range recommended by Respondent D which is in a span of 10 kilometers in radius. This is because transportation as mentioned by Respondent D is costly in the waste to energy conversion process. Figure 5 shows the current location of the timber collection centers in Bukit Rimau, Sungai Buloh, Rawang and Rasa as informed by Respondent D. The waste to energy plant is also located at Rasa.

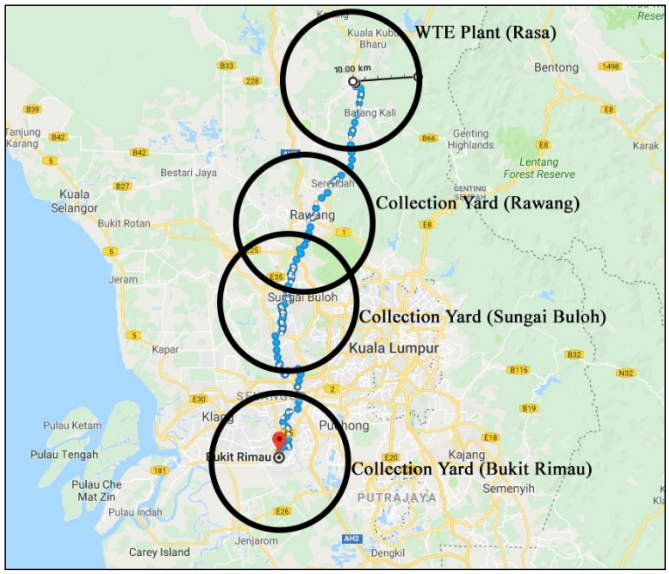

Figure 5: Existing location of timber waste reutilization and recycling in Malaysia.

From the list of location as shown in Figure 5, the line of transportation of the timber waste has shown a well coverage from Klang to Rasa in Hulu Selangor. However, there is lack of timber collection yard located at the Cheras and Kajang area. The map has further shown that mostly the timber waste collection for recycling started to accumulate in the Selangor area. The rest of the states have yet to reutilize and recycle the timber waste from the construction site. Thus, this discovery is in line with the survey with the timber waste contractors that could never send the construction timber waste to the recycling yard because there is no timber collection center located at their states.

The factors to improve the reutilization and recycling of construction timber waste by the timber waste contractors in Malaysia include:

i) Authority enforcement.

Based on the interview with the timber waste contractors, the contractor has voiced out that the authority enforcement is very crucial. This is because with the existence of the Act 672 on waste management but without enforcement to implement it, improvement could not be achieved.

ii) Revenue from selling the timber waste.

One of the contractors has informed that the revenue of selling the timber waste to the waste to energy plant is the most vital factor that encouraged the recycling of the timber waste. It is a norm for business's people to open business in order to get revenue.

iii) Limitation of landfill spaces.

With the declining of landfill spaces in Malaysia, the waste contractor found it difficult to deliver the waste to registered or legal landfill. Hence, other option is to recycle or reuse the timber waste in order to reduce the cost of sending the waste to landfill which require payment of Ringgit Malaysia 10 to 20 per tonne depended on landfill location.

iv) Public awareness.

The public awareness is a crucial effort to curb this waste of fuel. Malaysian has to change perspective that timber waste can be converted to energy. The waste to energy plant which takes only the waste wood as fuel can generate 6 Megawatts per hour to the Tenaga Nasional Berhad (TNB) power gridline. Hence, 6 megawatts of electricity can cater at least 13,680 houses. The timber waste in Malaysia can be sent to the recycling yard to segregate those usable timbers before sending the unusable timber waste to the recycling plant to be converted into energy. This practice is the best because it has optimized the usage of the timber waste rather than the common practice which is to send the timber waste to landfill directly from the construction site. However, some enhancements must be provided, and it is further elaborated in the recommendations of this research.

6. RECOMMENDATION

This study is focusing on finding the improvement factors of timber waste recycling in line with Act 672. Under the Section 10 of Act 672, it is mentioned on the reduction, reutilization and recycling of the waste. Hence, a review of the guideline in the construction waste may include the separation of timber waste according to the waste grade to provide a guide to the people involved in the construction field. Based on the example from the Community Wood Recycling in United Kingdom, the construction timber waste can be categorized into Grade B, C and D. The uncontaminated timber such as pallet is placed under category B to be reutilized. While the other timber wastes such as timber formwork and timber door which are contaminated with cement, paint and varnish may be placed into category C and D to be used a fuel or disposal at special facilities. The sortation at site will enable the selling of the timber waste at different grades to the recycling yard for a higher value.

Database system for the waste contractors interviewed in this research has shown that they are not concerned on the origin of the timber waste and the quantum of the waste collected. This is also mentioned in a research by Ng, Seow, and Tan (2017) that there are no systematic system record on the volume and types of construction waste generated in Malaysia. This has shown a disadvantage because database management is very crucial in storing information, sorting the data and improving from the previous data obtained. Besides to keep record of the timber waste collected by the waste contractors, the profit of selling the timber waste could also be recorded for future references. Hence, a good database management system shall be made mandatory to the waste contractors to improve on the current situation.

Logistic planning on the location of the timber collection yard and the project site shall be within the range recommended in a span of 10 kilometers as recommended by the waste contractor as economic convenience. This is because transportation is found to be costly in the waste to energy conversion process. Figure 6 shows the current location of the timber collection centers in Bukit Rimau, Sungai Buloh, Rawang and Rasa. The waste to energy plant is also located at Rasa.

Figure 6 also shown that the timber waste collection yard is mostly targeted at the Klang Valley area and has yet to reach out to the other states. In order to have a better coverage of the timber waste in the Klang Valley, a recommendation is to add another collection center either in Kajang or Cheras. It is recommended that the authority may collaborate with the timber waste contractors to increase the timber recycling facilities in Malaysia.

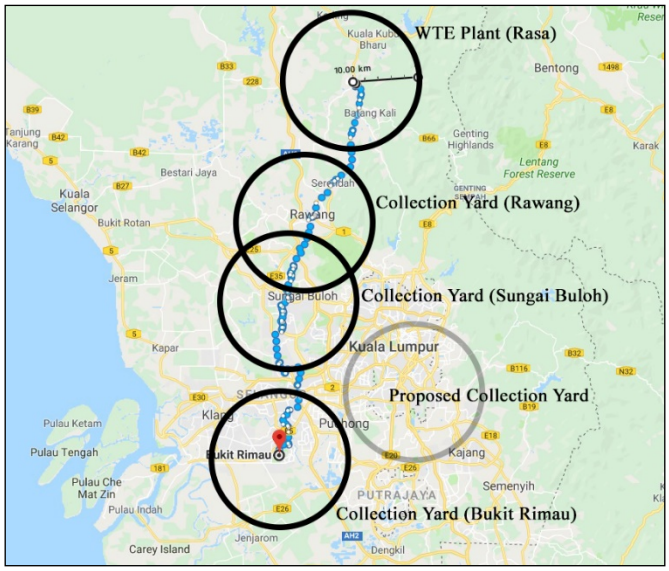

Figure 6: Existing location of timber waste recycling in Malaysia and proposed location of future timber collection yard.

Besides Klang Valley area, the rest of the states shall start to have awareness to recycle the timber waste in order to optimize the waste and to convert it into some useful energy that could bring benefit to the society. The authority may spread the circle of knowledge in timber waste recycling through education system and campaign.

7. CONCLUSION

Timber waste is one of major construction waste generated in the project site. To reduce the construction waste, timber waste generated from the site must be recycled. This study has discovered the improvement factors of this timber waste to be converted into electricity. Timber waste may replace the coal or fossil fuel that is not renewable and is the largest source of electricity in Malaysia. WTE appears to be more energy efficient type of energy recovery method than landfilling the timber waste in Malaysia. Many waste contractors are still not aware of this benefit and there is lack of government support to encourage these waste contractors to recycle the timber waste collected. Thus, the authority may take a serious lead on this matter to enhance and equip the waste contractors on this information. After all, this is to reduce the timber waste being sent to landfill.

8. REFERENCES

Ackerman, F. (2002). Waste, Recycling and Climate change US Perspective. In V. I. Grover, V. K. Grover & W. Hogland (Eds.), *Recovering Energy from Waste Various Aspects*. United States of America: Science Publishers, Inc.

Agamuthu, P., Hamid, F. S., & Khidzir, K. (2009). Evolution of Solid Waste Management in Malaysia: Impacts and Implications of the Solid Waste Bill 2007. *Journal of Material Cycles Waste Management, 11*, 96-103.

Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2006). A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia. *Resources, Conservation and Recycling, 48*(1), 86-98. doi: http://dx.doi.org/10.1016/j.resconrec.2006.01.004

CIDB Malaysia. (2015). CIDB Calls on the Construction Industry to Practice Sustainable Waste Management [Press release].Retrievedfrom http://www.cidb.gov.my/cidb2/images/content/pdf/siaran_akhbar/2015/CIDB_Waste_Management_17_November_2015.pdf

Community Wood Recycling. (2014). Waste Wood in the UK. Retrieved 5 March, 2017, from http://www.communitywoodrecycling.org.uk/learn-more/waste-wood/

Davies, W. M., & Beaumont, T. J. (2011). Case Studies: Research Methods.

Dimoudi, A., & Tompa, C. (2008). Energy and environmental indicators related to construction of office buildings. *Resources, Conservation and Recycling, 53*(1–2), 86-95. doi: http://dx.doi.org/10.1016/j.resconrec.2008.09.008

Fauziah, S. H., & Agamuthu, P. (2010). *Landfills in Malaysia: Past, Present and Future*. Paper presented at the 1st International Conference on Final sinks, Vienna.

Fink, A. (2013). *How to Conduct Surveys A Step-by-Step Guide* (5 ed.). United States of America: SAGE Publications, Inc.

Gritten, T. (2007). A Review of International Approaches to Waste Prevention and Minimisation. England: AEA Technology plc.

Gupta, J., & Gagnon-Lebrun, F. (2002). Waste, Energy & Climate Change. In V. I. Grover, V. K. Grover & W. Hogland (Eds.), *Recovering Energy from Waste Various Aspects*. United States of America: Science Publishers, Inc.

Kamar, K. A. M., Azman, M. N. A., & Nawi, M. N. M. (2014). IBS Survey 2010: Drivers, Barriers and Critical Success Factors in Adopting Industrialised Building System (IBS) Construction by G7 Contractors in Malaysia. *Journal of Engineering Science and Technology, 9*(No. 4), 490-501.

Krejcie, R. V., & Morgan, D. W. (1970). Determining Sample Size For Research Activities. 607-610. http://home.kku.ac.th/sompong/guest_speaker/KrejcieandMorgan_article.pdf

Kruger, D., Beer, T., Wainberg, R., & Huqinh, X. (2000). Solid Waste Management and Wastewater Treatment. *Methodological and Technological Issues in Technology Transfer, Intergovernmental Panel on Climate Change.*, 313-327.

Lim, J. (2017, 6 Nov 2017). A step closer to new era of waste management, *The Stars*.

Menon, P. (2017, 14 November 2017). Solid plan to manage waste, *The Stars*.

Merritt, J. A. (2002). Waste-to-Energy: Comprehensive Recycling's Best Chance? In V. I. Grover, V. K. Grover & W. Hogland (Eds.), *Recovering Energy from Waste Various Aspects*. United States of America: Science Publishers, Inc.

Ackerman, F. (2002). Waste, Recycling and Climate change US Perspective. In V. I. Grover, V. K. Grover & W. Hogland (Eds.), *Recovering Energy from Waste Various Aspects*. United States of America: Science Publishers, Inc.

Agamuthu, P., Hamid, F. S., & Khidzir, K. (2009). Evolution of Solid Waste Management in Malaysia: Impacts and Implications of the Solid Waste Bill 2007. *Journal of Material Cycles Waste Management, 11*, 96-103.

Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2006). A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia. *Resources, Conservation and Recycling, 48*(1), 86-98. doi: http://dx.doi.org/10.1016/j.resconrec.2006.01.004

CIDB Malaysia. (2015). CIDB Calls on the Construction Industry to Practice Sustainable Waste Management [Press release].Retrievedfrom http://www.cidb.gov.my/cidb2/images/content/pdf/siaran_akhbar/2015/CIDB_Waste_Management_17_November_2015.pdf

Community Wood Recycling. (2014). Waste Wood in the UK. Retrieved 5 March, 2017, from http://www.communitywoodrecycling.org.uk/learn-more/waste-wood/

Davies, W. M., & Beaumont, T. J. (2011). Case Studies: Research Methods.

Dimoudi, A., & Tompa, C. (2008). Energy and environmental indicators related to construction of office buildings. *Resources, Conservation and Recycling, 53*(1–2), 86-95. doi: http://dx.doi.org/10.1016/j.resconrec.2008.09.008

Fauziah, S. H., & Agamuthu, P. (2010). *Landfills in Malaysia: Past, Present and Future*. Paper presented at the 1st International Conference on Final sinks, Vienna.

Fink, A. (2013). *How to Conduct Surveys A Step-by-Step Guide* (5 ed.). United States of America: SAGE Publications, Inc.

Gritten, T. (2007). A Review of International Approaches to Waste Prevention and Minimisation. England: AEA Technology plc.

Gupta, J., & Gagnon-Lebrun, F. (2002). Waste, Energy & Climate Change. In V. I. Grover, V. K. Grover & W. Hogland (Eds.), *Recovering Energy from Waste Various Aspects*. United States of America: Science Publishers, Inc.

Kamar, K. A. M., Azman, M. N. A., & Nawi, M. N. M. (2014). IBS Survey 2010: Drivers, Barriers and Critical Success Factors in Adopting Industrialised Building System (IBS) Construction by G7 Contractors in Malaysia. *Journal of Engineering Science and Technology, 9*(No. 4), 490-501.

Krejcie, R. V., & Morgan, D. W. (1970). Determining Sample Size For Research Activities. 607-610. http://home.kku.ac.th/sompong/guest_speaker/KrejcieandMorgan_article.pdf

Kruger, D., Beer, T., Wainberg, R., & Huqinh, X. (2000). Solid Waste Management and Wastewater Treatment. *Methodological and Technological Issues in Technology Transfer, Intergovernmental Panel on Climate Change.*, 313-327.

Lim, J. (2017, 6 Nov 2017). A step closer to new era of waste management, *The Stars*.

Menon, P. (2017, 14 November 2017). Solid plan to manage waste, *The Stars*.

Merritt, J. A. (2002). Waste-to-Energy: Comprehensive Recycling's Best Chance? In V. I. Grover, V. K. Grover & W. Hogland (Eds.), *Recovering Energy from Waste Various Aspects*. United States of America: Science Publishers, Inc.

Moh, Y., & Abd Manaf, L. (2016). Solid waste management transformation and future challenges of source separation and recycling practice in Malaysia. *Resources, Conservation and Recycling, 116*, 1-14. doi: http://dx.doi.org/10.1016/j.resconrec.2016.09.012

Nagapan, S., Abdul Rahman, I., & Asmi, A. (2012). *CONSTRUCTION WASTE MANAGEMENT: Malaysian Perspective*. Paper presented at the International Conference on Civil and Environmental Engineering for Sustainability, Johor Bahru.

Ng, L. S., Seow, T. W., & Tan, L. (2017). *Current practices of construction waste reduction through 3R practice among contractors in malaysia: Case study in penang*. Paper presented at the IOP Conference Series: Materials Science and Engineering.

Oladimeiji, A. A., Kumar, S., Parekh, C. T., & Bhala, M. J. (2002). Energy-from-Waste: A Perspective from Developing Countries. In V. I. Grover, V. K. Grover & W. Hogland (Eds.), *Recovering Energy from Waste Various Aspects*. United States of America: Science Publishers, Inc.

Porteous, A. (1981). *Refuse Derived Fuels*. London: Applied Science Publishers Ltd.

The Sun. (2017). Rising fuel costs raising electricity prices, *The Sun*.

Thorneloe, S., Roquetta, A., Pacey, J., & Bottero, C. (2000). Database of Landfill-Gas-to-Energy Projects in the United States. http;//216.55.25.242/msw_0003_database.html

Wang, L., Chen, S. S., Tsang, D. C. W., Poon, C. S., & Shih, K. (2016). Value-added recycling of construction waste wood into noise and thermal insulating cement-bonded particleboards. *Construction and Building Materials, 125*, 316-325. doi: http://dx.doi.org/10.1016/j.conbuildmat.2016.08.053

Weisleder, S., Nasseri, D., & Elbstr, G. (2006). Construction and Demolition Waste Management in Germany. Germany: ZEBAU GmbH.