Smart Waste Recycling within the Sustainability Framework at Higher Educational Institution

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ABSTRACT

Most of the crucial sustainability action plan within the most impactful sustainable campus is identifying a relevant mechanism in transformation waste-to-wealth concept. Universiti Teknologi Malaysia (UTM) waste management programs are designed to protect the environment, reduce pollution and encourage recycling throughout community. The challenges offer multi-decision practice at the operational services as to serve in Living Laboratory, which empowers operational services, academic and research elements in Sustainability Development Goals. The study is aiming to assist the structural operation framework, legalize action plan and improve the facility based on Zero Waste outcome within the campus authority. The authorization of framework suggested from incoming waste material in the streamline, further introduce the Smart Waste Recycling policy and increase the participant from campus citizen. Waste management in campus is facing common issues of improper waste handling by contractor, disposal criteria, and ineffective mechanism of waste segregation which eventually lead to the involvement of high and burdensome operational cost. This short review represent the current initiatives and impactful program in the Universiti Teknologi Malaysia (UTM) and provides some viewpoint in the conclusion to improve the current Smart Waste Recycling implementation with an objective to address problems that have been aforementioned and highlights its market potential for institutional income, especially to be addressed by higher institutions.

Keywords: Sustainability Waste; Bio-recycling; Living Laboratory; Smart Management, SDGs.

Introduction

With the growing number of universities, the population of each campus is significant and generate waste that causes adverse impact to the environment. It is estimated that waste from all academic institutions amounted to approximately 1,500 tonnes per day, which represents

5-10% of the total waste generated in Malaysia [1]. Higher Education Institutions (HEIs) are change agents that bear the ethical responsibility to promote sustainability and environmental awareness of people inside and outside universities. HEIs need to serve as role models in their communities, as well as leaders in social and environmental responsibility whom engaged in sustainable development by providing linkages between knowledge and dissemination in the community; as well as by serving back to societal development through outreach and use of knowledge to serve society [2]. On the scale of a small city HEIs require services and infrastructure which from these activities generate an environmental impact. Nowadays, many HEIs have accepted the challenge to minimize this impact applying several measures. One of the impacts to be reduced is in the solid waste management sector of divert waste to landfill.

Waste management in higher education institutions is generally a complex and multidisciplinary activity, which demands supports from various stakeholders. Determining waste characteristics from specific departments or clusters provide avenues for establishing sound waste management strategies [3]. The population of students and employees, workshops and laboratory activities, cafeterias and food related stalls, infrastructure repair and maintenance, and the utilization of energy and materials equate to a positive correlation in generated wastes. As a result, significant environmental impacts arise from the volume and variability of materials required to support such in campus operations. It is therefore important for HEIs to manage solid wastes in a sustainable and efficient manner [4].

Solid waste generation in Malaysia is increasingly rising, from 30,000 tonnes per day in 2015 to 38,000 tonnes per day today. However, the recycling rate in Malaysia which was officially announced by the Federal Government in 2016 is 11.0%. There are almost 176 landfills in the country, but only eight are sanitary landfill, leaving the rest merely open dumpsite. In the 10th Malaysia Plan, the government targeted the recycling rate to be 22% by 2020 [5]. It is essential to achieve this recycling rate in order to reduce the negative environmental impact, reducing GHG emissions and to develop a sustainable solid waste management in Malaysia which is on par with the developed countries. With the increasing numbers of public and private universities in our country, the population of each campus is significant and the waste generated will have impact on the environment if not properly controlled [6]. With the generation of waste between 5-8 tonnes per day, it is estimated that waste coming from academic institutions amounted to approximately 1,500 tonnes per day, comprising approximately 5-10% of the total waste generated in Malaysia [7]. As the premier university in the country, University Teknologi Malaysia (UTM) is also embracing the move towards sustainability.

Universiti Teknologi Malaysia (UTM) as a leading innovation-driven entrepreneurial research university in engineering science and technology taking sustainability seriously by incorporate Sustainable Development Goals (SDGs) and Education for Sustainable Development (ESD) thorough a comprehensive framework of research integration, educational and operational subsidiary was constructed to balance of academic and non-academic implementation. This research aims to explore the potential of recovering and valorising source-segregated food waste and mixed waste from the UTM campus into bio-commodities how circular economy thinking can be incorporated in waste management strategy in higher education instutuion and their adjacent communities through synergistic utilisation of resources, i.e. an integrated and collaborative approach.

Resolve for Future Sustainable Campus

The university determination towards sustainability at campus reflected through detailed planning and UTM sustainable policies (UTM-P). Totally there are fifteen policies (UTM-P1 to UTM-P15) was introduced and being executed for sustainable practice inside campus [8]. Sustainability already incorporated into University Global Plan phase I and II from 2012-2017. From position 85 in 2010 UI Greenmetric ranking, UTM elevates by leaps and bound to positon 66 in 2017. Based on the excellent achievement, UTM-CS has won two awards in 2017: Kelestarian Kampus Hijau Universiti Awam Malaysia (Malaysia Public University Green Sustainable Campus) from Ministry of Energy, Green Technology and Water (KeTTHA) and also Diamond Recognition Certificate LCCF Award Recognition Ceremony & Low Carbon Cities Framework (LCCF) Implementation Sharing Session.

To step up the game, UTM have executed the University Global Plan phase III (2018-2020) which consist of introduction of in-campus electric bus project, development of database of national and international sustainability awards and enhance "Waste-to-Wealth", "Recycle, Reuse, Reduce (3R)" programs. Universiti Global Plan III (2018-2020) is developed based on six main key focus areas namely: 1. Excellence in Learning and Teaching, and Transformative Campus Experience, 2. Research Excellence, Industry and Community Engagement, 3. Sustainable Campus, Infrastructure, Information and Communication (ICT) System, 4. Talent Transformation, Governance and High Performance Delivery, 5. Advancement and Business Development for Financial Sustainability, and 6. Global Prominence and Branding. The six main focus areas are translated into Strategic Objectives (SO) and Key Amal Indicators (KAI) of various initiatives and programs to be implemented. The success of PGU Phase III is dependent on four core values: Integrity, Synergy, Excellence and Sustainability towards universal well-being that strives for the good of the stakeholders, mainly the community and industry. The third phase also inculcates volunteerism among staff and students on its implementation. UTM Master Plan 2017-2037 for future administrator guideline [9].

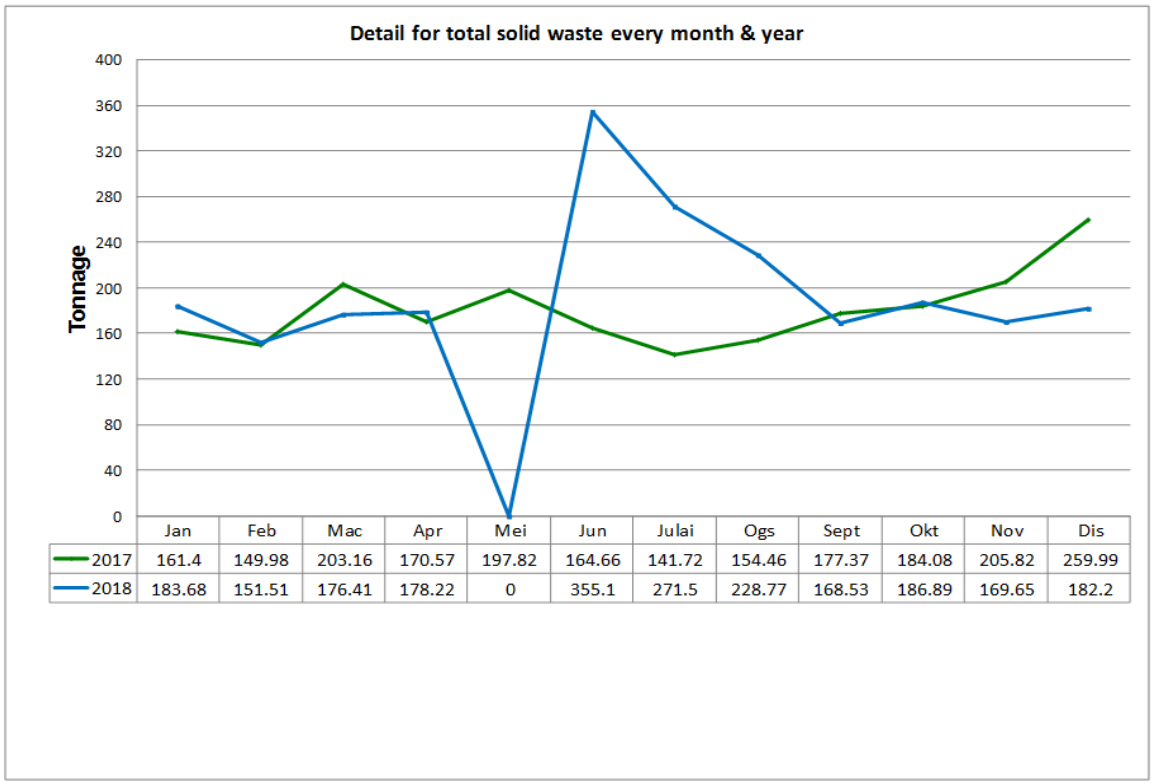
Living Laboratories of UTM

Living Laboratories (LL) The concept of LL can be interpreted and used as a human-centric research and development approach. LL approach not only focuses on involving students in development process, it also strives to facilitate the interaction among other relevant stakeholder, such as academia, researcher, administrative personnel. A university would operate as a fully integrated community that models social and biological sustainability it self. In many cases, people think on education, research, operation as separate activities but they are not actually. Because students learn from everything around them, these activities (E,R,O) form a complex of experience and learning. In order to graduate, students need to overcome this larger, extensive form of learning, education experience must reflect on intimate connection among curriculum and research; understanding any negative ecological and social footprint of the institution and improve local and regional communities to more healthier and environmental sustainable. Therefor, the concept of LL is good approach to enhance the sustainable development in UTM.

UTM Bio-recycling Centre as Core Element in Living Laboratory

These initiatives reflect good health and well-being (SDG 3) and responsible consumption and production (SDG 12). Bio-recycling Centre is created to integrate the collection of wastes from various sources, such as food waste, green waste and solid waste, in order to promote

the healthy lifestyle and further practicing the entrepreneurial spirit among university's citizen. Through some researches and sustainable practices, the implementation of Sustainable Arcade (Green Cafetaria) and Bio-Recycling Centre in UTM shows some improvement in the waste management since it was implemented on 2010 [10]. Through the UTM Campus Sustainability flagship project, a total of 15 researchers have conducted a 7 months research on project title "On-Campus Bio-Recycling Of Food and Green Waste Into Compost" in order to produce a feasibility report on scaling up the bio-composting process and also to scale up the current practice in amount of food waste collection (100 kg/day to 600 kg/day). This ongoing research has become a gateway for UTM functionality as a Living Laboratory towards Zero Waste Society and creating a small scale composting of food and green waste. The quantity of food waste (kg) collected since Jan 2017 to Dec 2018 has been recorded (Figure 1). However, this data only represent for 2 sustainable arcades at that time, namely Meranti and Cengal.



	Jan	Feb	Mac	Apr	Mei	Jun	Julai	Ogs	Sept	Okt	Nov	Dis
2017	161.4	149.98	203.16	170.57	197.82	164.66	141.72	154.46	177.37	184.08	205.82	259.99
2018	183.68	151.51	176.41	178.22	0	355.1	271.5	228.77	168.53	186.89	169.65	182.2

Figure 1 – Summary of food waste management

Therefore, the roughly amount of food waste in tonnes per year is about 27.59 t/year. Out of the amount of average food waste dispose to the landfill, only 4% will be separated for purpose of bio-product processing with 60% of it will be used to produce the bio-compost fertilizer, while 40% will be focused on the production of feedstock. Currently, there is 4 arcades namely Meranti, Chengal, PHB and Kolej 9 engaged in the production of bio-compost fertilizer and feedstock .The solid waste around the UTM campus was collected under the responsibility contractor, Tahang Sdn. Bhd. up until now. At present, the 2% separation of food waste for bio-compost product did not happen at rest of 114 cafeterias in this campus. Problem such as the difficulty in finding the previous data especially on how much food waste generate from the solid waste for the rest cafeteria in UTM campus is one of the constraints [11]. The A materialflow diagram showing the generation,distribution, treatment and disposal of food waste in UTM is shown in the figure 2. The source analysis has shown that there is a great opportunity of utilising the foodwaste from campus. The food

waste whichis currently sent for biorecyling center can be recyled in to fertilizer, feedstcok, and energy. The 30% trash cans are collected in the bins and seperated and recyled. While 100 % of the food waste are processed in the biorecyling center and utlised in biowaste farm projects namely biocompost fertilizer and animal feedstock. The value added products are finally sold as commodities in to market.

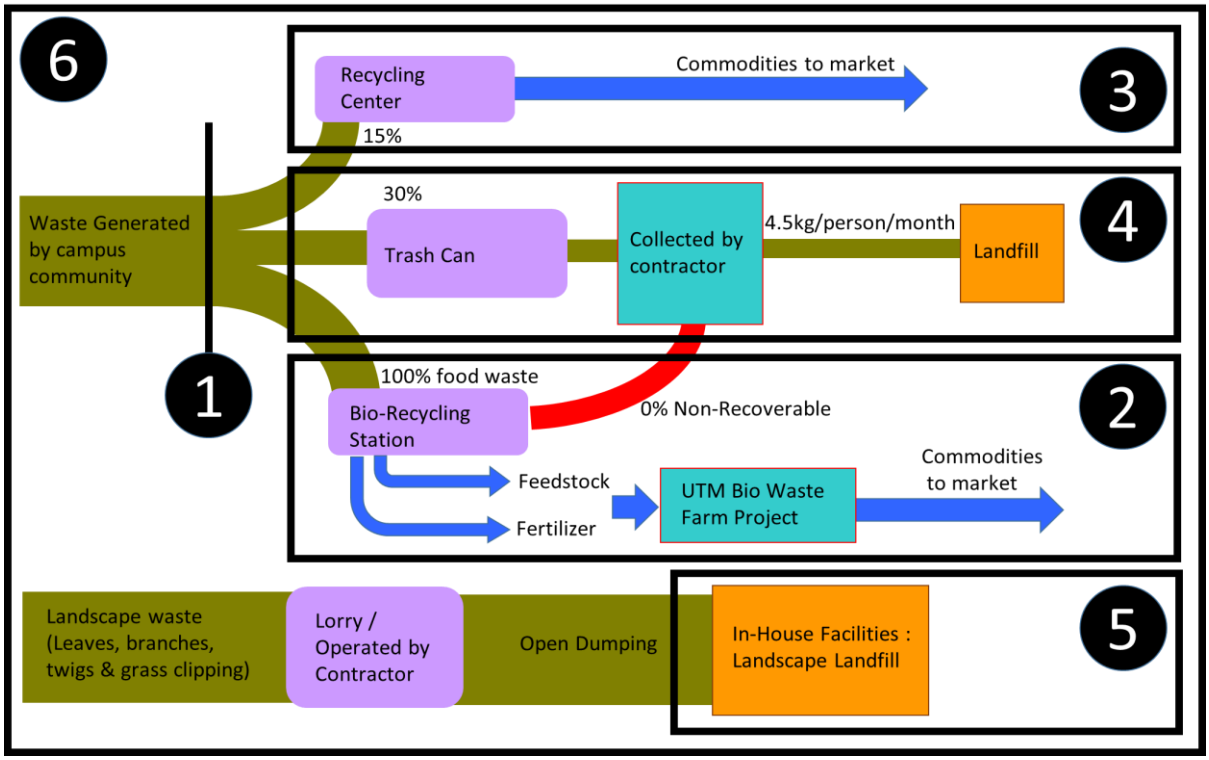


Figure 2 - Framework of UTM Campus Sustainablity

The increment of waste management expenses for operational management has become a major factor that inhibits the solid waste management in general. Failure in disseminating and integrating the best practices among the campus citizen and operational of cafeteria waste have significantly contributed to the increment of operating cost. The situation worsened as there is no awareness for sustainable entrepreneurship mechanisms to optimize the operation costs and awareness campaign. Therefore, UTM has utilize the Bio- Recycling Centre to develop the potential of income generating from campus food waste, including the marketing of the end products. This initiative aims for two types of end product with a high commercial potential, namely; 1) Bio-Compost Fertilizer and 2) animal feed production. These products usually purchased from external parties for campus's internal usage (e.g. landscape, plantation and animal feeds). Since 2010, these products purchased were reduced significantly from 5–10%, which clearly minimize the expenditure bills for UTM. Roughly, about 100 kg/day feedstock produced from food waste (data obtained from 4 cafeterias', out of 114), and the number is increasing through populations. From total feedstock produced, the percentage of 15 till 20% of the food waste from cook and non-cook is targeted for fertilizer, while 55 until 27% for livestock.

Animal Feedstock

Meanwhile, for animal feedstock, the collected food waste will undergo several steps before ready to be used as feedstock and for commercial packaging (Figure 3). The collected food waste will be manually segregated to separate the solid waste and food waste, the leachate

collection, before its' nutrition enriched with the mixture of coconut pulp and wheat flour (for livestock growth rate), and allowed to dry before it can be applied fosr the livestock such as chickens, lambs and ducks at UTM farm. These products have been tested to livestock at the UTM farm and the result showed the higher nutrition content in the feedstock indicated a positive development towards the growth of livestock compared to the normal feedstock purchased from the external parties.

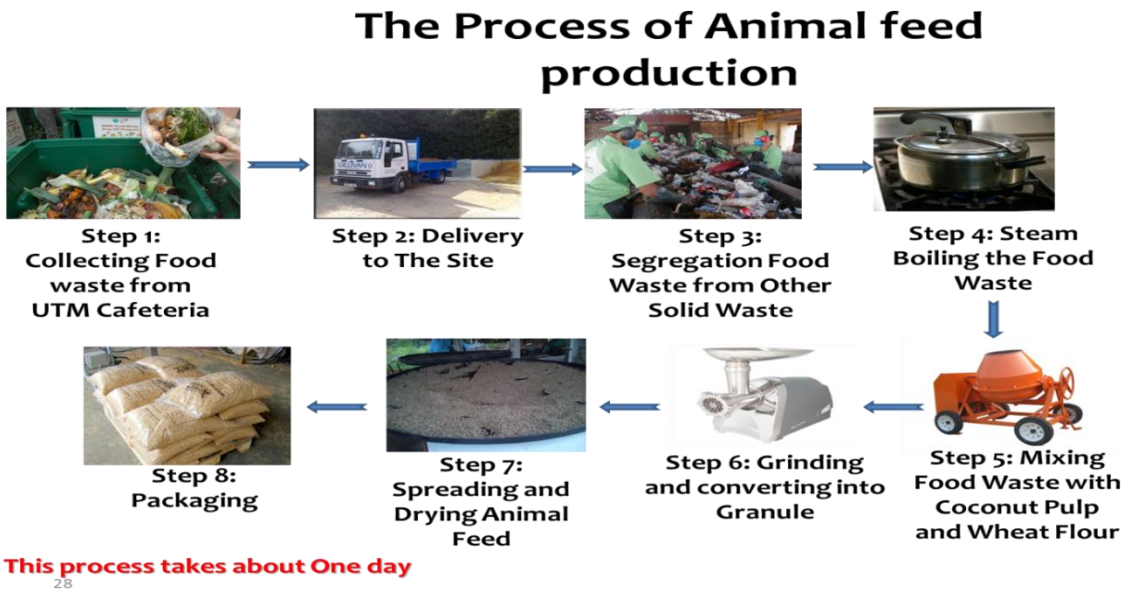


Figure 3 – Process of Animal feed production

Biofertilizer

The workflow of the biocompost fertilizer in UTM is given in the Figure 4. Composting is an aerobic process that involved the biologically decomposition of the organic material which eventually produced carbon dioxide, water and heat. It is widely used as soil conditioners and soil fertilizers. The application of bio-compost as soil conditioner will increase the rate of plant growth during the photosynthesis and reproductive phase [12]. Significantly, it will also increases the hormones for plant growth and nutrient absorption, thus providing resilience ability towards drought and moisture stress [13]. Basically, the production of bio-compost fertilizer will involve the food waste collected from food arcades around the campus and further process is to mix up with shredded garden waste. Effective Microbes (EM) that has been produced by university's researcher was used as natural accelerator for decomposition processes.

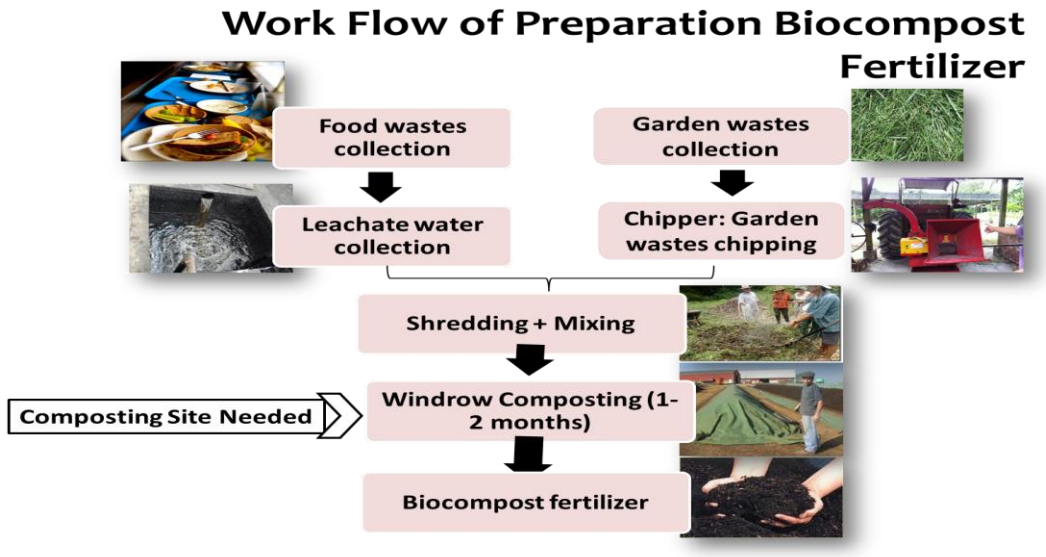


Figure 4 – Steps invloved in preparing biocompost fertilizer

Biocoke

Bio-coke is an environment-friendly biomass fuel that can be made from almost any photosynthetic plant, including what had been considered waste materials, such as used tea leaves and coffee grounds. An effective form of waste management, bio-coke is also seen as a way to counter the over-reliance on fossil fuels and the risks associated with fluctuations in fossil fuel import prices. Someday, bio-coke might replace the coal that industries currently use as a solid fuel for smelting iron, leading to a significant reduction in CO_2 emissions**.**

The workflow of biocoke production is given in the Figure 5. The collection of landscape wastes is done daily with as much as two trips for some cleaning zones. Collection forms were distributed to all contractors for the eleven zones and they are required to complete the form and give back to the person in charge in office of the assets and development. Lorries weighing three tonnes are used to collect the landscape waste. The contractors used weighting scale to estimate the weight for each gunny sacks containing dry leaves, while other landscape wastes such twigs, branches, palm frond, and wood are directly loaded into the lorry. The weight of each gunny sacks will be estimated by the contractors by taking the average weight of the dry leaves in the gunny sacks. The biocoke was prepared using different ratio of EFB to dry leaves ratio such as 90:10, 50:50, and 0:100. After pyrolysis, the biomass showed increase in carbon content it is attribute to the great influence of dehydration which also makes a slight reduction of hydrogen content indicating that the bio-coke produced at moderate temperature was pyrolyzed more thoroughly [14]. The products, generated by the polymerization of these radicals and precursor which is formed by the macro-molecules cracking, deposit on the EFB: dry leaves biocoke leading to increase in C and H content. It is ascribed that the large amount of dehydration which reduces the chemical bonds resulting in an increase in the relative proportion of oxygen-free functional groups [15].

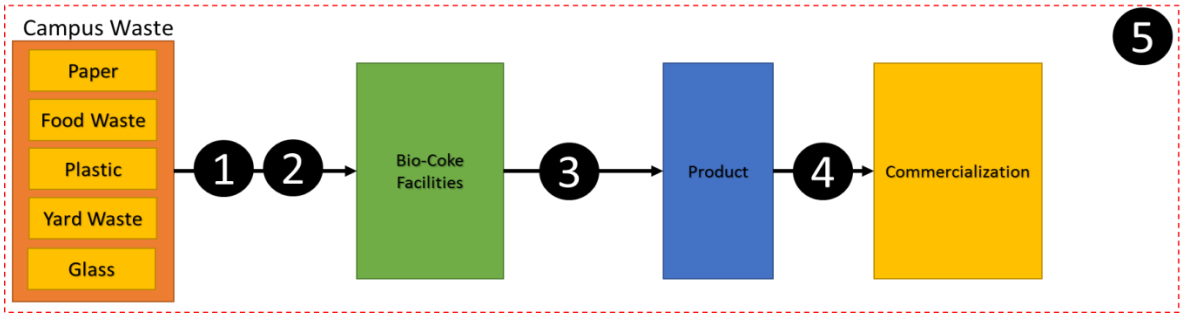


Figure 5 – Waste management for Biocoke production.

Strategies for Zero Waste Policy for Sustainable Services and Green Campus

Solid waste management systems adapted from waste characteristics and conditions with specific scales and contexts in consideration, will be much more effective than systems simply imitated somewhere else The cafeteria for example generates a huge volume of food refuse, thus, waste management systems in place should be able to prioritize reducing, recycling, and storing food-related wastes. In addition to food wastes are packaging wastes that when disposed in open areas with no cover or protection against rainwater accumulation, can become a breeding site for disease vectors that may lead to severe sanitary problems. Despite the fact that HEI community is well aware of organic waste and resource recovery issues, building a zero waste campus community requires some prerequisite actions. These include by having a proper policy, guidelines and enforcement compliance for recovering resources such as energy, nutrient and products that can further be harvested through composting and recycling [16].

Inadequate and inefficient waste collection, recycling or treatment, and uncontrolled disposal of organic waste in dump areas could cause severe effects such as health risks to human beings and pollution to the environment. Majorly, the waste management can be handled properly if the policy, acts and guidelines are disseminated into level of action. Most of the action suggested under the recommended sub-actions is require to the involvement of relevant stakeholders and the community within the proposed national blueprint [17].

Another important determinant in campus waste generation involves consumption behaviors and purchasing habits of campus communities. Reducing the university's consumption is crucial to begin any creation of a sustainable waste cycle.Thus, focus to change them to reduce waste tonnage, and recover waste as a resource through sustainable management habits is the key pre-requisite. This along aggressive efforts to update existing or planned as well as expand the waste reduction and recycling program will help in achieveing the zero-waste target and ensure effective utilization of natural resources, due to expanding campus population growth, and economic potential. In addition, it assists with the education of the campus community around responsible purchasing habits, consumption behaviors, and responsible living for a sustainable future [18].

Smart Waste Recycling Policy

Implementation of Waste Separation at Source programme will be the major consideration to standardize the level of solid waste management and public cleansing across all Local Authority (LA) regardless of income; and to create economies of scale for appointment of contractors. It is an important element in carrying out 3R (Reuse, Reduce, Recycle) practices successfully. Recyclable wastes are successfully being separated and sent for recycling purposes, while the residual waste can be used for composting purposes. Besides that, pairing of practices on waste separation at source and 3R will significantly reduce the amount of waste sent to land-fill for disposal [19]. Recyclable wastes are successfully being separated and sent for recycling purposes, while the residual waste can be used for composting purposes. Besides that, pairing of practices on waste separation at source and 3R will significantly reduce the amount of waste sent to landfill for disposal. Another framework of policy and regulatory action is the standard of incoming waste oil to prevent secondary pollution. This criterion will allow only registered and certified companies with adequate facilities to venture into recycling used oil operation.

Malaysia, there is currently no mandatory enforcement on the PAYT program but this act has been introduced in the Solid Waste Management and Public Cleansing Act (2007) in Part V, Sections 30, 31 and 32. See Sections 30(3) & (4) is introduced the Take Back and Deposit Refund System. The implementation of this category "Pay as You Throw" (PAYT) program is based on a concept of usage-pricing when disposing municipal solid waste. This is fall under the Thrust 1: Minimization of the Solid Waste Generation. It imposes charges to households for solid waste collection based on the amount of waste being thrown away. The charges will support the conservation program and eco-city activity. By applying this concept, such of the downstream approach is needed, for example, people engagement toward practicing the "fork-to-farm" concept. As this is expecting to commence in 2018, thus a realistic strategy including funding mechanism is a must [20].

Public consensus is important and campaigns targeting on public awareness and consensus on the benefits of reducing waste, recycling and composting, consequences of landfilling of organic waste and illegal dumping needs to be frequently organized. The role of enterprise in the PAYT mechanism is important and a Public Private Partnership (PPP) relationship should be established. Rewarding and sustainable incentive could be the major part in the PAYT, as to promote the ecological zone [21]. Landfilling has shown from many scientific evident is not the best technology in dealing with organic waste since it required high demand for land. Moreover, landfilling of organic waste releases methane gas (CH4), with a global warming potential (GWP) that is 24 times higher than carbon dioxide. Therefore, the proposal is to look into any possibility or encouragement from the policy-into-action and stakeholders involvement.

Conclusion

Universiti Teknologi Malaysia (UTM) waste management programs are designed to protect the environment, reduce pollution and encourage recycling throughout community The Bio-Recycling Centre is still in the process of implementation and it cope with some issues that constrain the effectiveness of its' implementation in the campus. Introduction of Zero Organic Emission Society at local and national levels by creating new environmental towns at the local level is the key element in providing the critical Zero Organic Waste Index during the practices of PAYT and Zero Waste Culture Scheme. This could empower various stakeholders as the initiative of PPP. Usually, the Eco-Town is to achieve Sustainable Consumption and Production (SCP) by means of information access, market creation and networking, policy and strategy development, regional corporation, building sustainable

commitment and others. Altogether, the low carbon city and Sustainable Development Goal (SDG) would be highly recommended for the policy into action.

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References

[1] William McDonough & Partners, 1992. The Hannover Principles: Design for Sustainability. https://www.mcdonough.com/wp-content/uploads/2013/03/ Hannover-Principles-1992.pdf. (Accessed 21 January 2019).

[2] Kannahi M, Ramya R (2015) Effect of Biofertilizer, Vermicompost, Biocompost and Chemical Fertilizer on Different Morphological and Phytochemical Parameters of Lycopersicum Esculentum L. World Journal of Pharmacy and Pharmaceutical Sciences 4: 1460-1469.

[3] Wilson, D.C., Velis, C.A., Rodic, L., 2013. Integrated sustainable waste management in developing countries. Waste. Resour. Manage. 166 (WR2), 52e68.

[4] Ahmad AR, Soon NK, Ting NP (2015) Income Generation Activities among Academic Staffs at Malaysian Public Universities. Canadian Center of Science and Education Publisher 8: 194-203.

[5]http://vodppl.upm.edu.my/uploads/docs/The%2010th%20Malaysia%20Plan%202_Summary.pdf Tenth Malaysian plan.

[6] Yusoff, S. (2018). Toward integrated and sustainable waste management system in University of Malaya: UM zero waste campaign. In *E3S Web of Conferences* (Vol. 48, p. 04007). EDP Sciences.

[7] Kam, H. W., Baharum, M. R., & Chua, S. J. L. (2016). A review of commercial waste recycling policy in Malaysia. *International Journal of Environment and Sustainable Development*, *15*(4), 404-422.

[8] O. Saadatian, K. B. Sopian, E. Salleh, Sustainable Cities and Society. Adaptation of sustainability community indicators for Malaysian campuses as small cities, 6, 40-50 (2013).

[9] Yang H, Huang L, Liu S, Sun K, Sun Y. Pyrolysis process and characteristics of products from sawdust briquettes. Bioresources 2016;11:2438–56.

[10] http://www.utm.my/sustainable/our-policy/.

[11] K. Tenaga, & T.H. Air, Low carbon cities framework & assessment system, ISBN-978-967-5893-06-3. (2011).

[12] UTM Sustainability Report, UTM press, Towards Low carbon campus, ISBN-978-967-0194-43-1. (2013).

[13] [15] R. Zakaria,E. Aminudin, UTM press, Sustainable development campus, ISBN-978-983-52-1478-3 (2017).

[14]. Montiano MG, Diaz-Faes E, Barriocanal C, Alvarez R. Influence of biomass on metallurgical coke quality. Fuel 2014;116:175–82.

[15] I. S. Zen, R. Ahamad, & W.Omar, Jurnal Teknologi. The development and measurement of conducive campus environment for Universiti Teknologi Malaysia (UTM) of campus sustainability, 68(1) (2014).

[16] Tang, W. C., Nirmal, U., Lau, S. T., & Murugan, S. (2019). A Review on Managing Solid Waste Produced from Homes in Malaysia. *Current Journal of Applied Science and Technology*, 1-23.

[17] Ufua, D. E., Olokundun, A. M., Ogbari, M. E., & Atolagbe, T. M. (2019). ACHIEVING ZERO WASTE OPERATION IN A PRIVATE ORGANISATION THROUGH EXTENDED STAKEHOLDERS CONSULTATION: A CASE IN THE NIGER DELTA REGION, NIGERIA. International Journal of Mechanical Engineering and Technology (IJMET), 10(2), 155-168.

[18] Clark, J. H. (2019). Green biorefinery technologies based on waste biomass. *Green Chemistry*.

[19] Jyothi, P., Vatsala, G. A., & Gupta, R. (2019). Goal Programming Model to Budgetary Allocation in Garbage Disposal Plant. In *Logistics, Supply Chain and Financial Predictive Analytics* (pp. 77-90). Springer, Singapore.

[20] El Sheltawy, S. T., Boghdady, N., & Fouad, M. M. K. (2019). Improvement of Solid Waste Management Code of Practice Development Through Effective Public Consultation. In *Waste Management and Resource Efficiency* (pp. 147-157). Springer, Singapore.

[21] Xiao, C., & Buhrmann, J. (2019). Ideas to action: environmental beliefs, behaviors, and support for environmental policies. Journal of Environmental Studies and Sciences, 1-10.