Circular Economy in Malaysia

P. Agamuthu and S. B. Mehran

Abstract Circular economy is a concept that aims to improve resource efficiency by minimizing resource consumption and waste generation. The implementation of circular economy can be conducted at three levels: in single enterprise or group of enterprises, in a group of collocated firms and at the city or municipal level. Currently, implementation of circular economy in Malaysia is at firm level. There is a lack of legal framework on the implementation of circular economy in Malaysia. However, there are certain sections and regulations in Environmental Quality Act 1974, Solid Waste and Public Cleansing Management Act 2007 and in Environmental Quality (Scheduled Waste) Regulation 2005, respectively, that promote resource circulation. Nationwide initiatives taken to promote circular economy are inclusion of integration of sustainable production and consumption, reduction of 40% of greenhouse gas emissions intensity from GDP compared to 2005 level and 22% of recycling of MSW, in Eleventh Malaysian Plan. Additionally, SWCorp has launched SWCorp Strategic Plan to promote sustainable solid waste management services, and CIDB has initiated CITP that has a target of incorporating 20% of recycled construction and demolition waste (tonnage) by year 2020 from baseline of 2016. Also, there are guidelines on coprocessing and proposals on establishment of industrial ecology by DOE. A few case studies show implementation of circular economy in manufacturing industries. The benefits of these implementations were reduction in energy and resource consumption, reduction in waste generation, protection of environment and human health, cost savings by reusing or recycling waste and additional profit gains by selling waste to potential buyers. Several opportunities of sustainable waste management and resource circulation have been highlighted in this chapter such as manufacturing of bioproducts and butanol from biomass to coprocessing between ELVs and construction industry. To successfully implement circular economy, top-down and bottom-up approach is required, and currently, Malaysia does not have explicit top-down and bottom-up approaches.

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1 Introduction

Circular economy (CE) or the closed-loop economy is a concept that aims to improve resource efficiency by slowing, closing and narrowing material and energy loops to minimize overall resource and energy input and as well as waste generation (Ghisellini et al. 2016). It is suggested that circular economy can be implemented at three levels: in single enterprise or a group of enterprises, in a group of collocated firms and at city or municipal level. At the first level, resource and energy efficiency are achieved by implementation of cleaner production in a single enterprise or in a group of enterprises. To implement CE at the second level, the establishment of eco-industrial parks or industrial symbiosis is required by collocating a group of firms, e.g. Kalundborg, Denmark. The outcome is the enhancement of collective energy and resource efficiency by sharing a certain stream of energy and resources. Third level, so far mainly found in China, requires whole municipal area or city that engages in recycling and interconnected processes with the help of economic and administrative incentives (Mathews and Tan 2011).

Conceptually, circular economy is currently being promoted by European Union and other nations such as Germany, France, Canada, China and Japan (Korhonen et al. 2018). In Asia, China and Japan are the two countries that have institutionalized circular economy. In 2008, China enacted the legislation on circular economy which came into effect the following year, 2009. Unlike most countries in the world, circular economy is not incorporated in environmental policy in China, but it is rather in the national development and economic policy. In the world, China is the first country to incorporate circular economy in the national strategy of economic and social development; whereas, Japan, USA and Germany, have incorporated circular economy in environmental and waste management policies (Ghisellini et al. 2016). China is the only country at present, where the top-down approach (through institutionalization) is being complimented by a bottom-up approach (private initiatives taken at firm levels) to implement circular economy.

Circular economy in Malaysia is still an unofficial long-term goal as the legal framework is lacking. But there have been sporadic practices of cleaner production at firm levels in Malaysia. Legal framework for waste management, in the light of circular economy, is still in its early stages as only in 2007, and Solid Waste Management (SWM) Act was introduced in Malaysia (Fauziah and Agamuthu 2012). In this SWM Act, main emphasis has been given on segregation at source and recycling in municipal solid waste. On the contrary, the practice of 3R and/or decoupling of resource consumption from economic development is not part of the legislation on hazardous waste in Malaysia. However, there are proposals and programs for initiation of industrial ecology and eco-waste parks in government agencies like Department of Environment (DOE) Malaysia and Malaysian Investment Development Authority (MIDA), respectively. There have also been practices of waste exchange and reuse of hazardous waste in Malaysia, but it is not widely practised among industries. DOE Malaysia has also been promoting coprocessing, especially in cement manufacturing plants since May 2015. All nine cement plants in Malaysia are practicing coprocessing at present. Yet, no clear pattern of reduction in the generation of hazardous waste from industries was observed in the last seven years.

The terminology used for waste exchange by DOE is coprocessing. Coprocessing is defined as waste utilization as raw material or as energy source or both in a manufacturing process. Therefore, the practice of waste exchange in this chapter will be mentioned as coprocessing. Lastly, hazardous waste is referred as scheduled waste in Malaysia. Hence, the hazardous waste will also be described as scheduled waste from here on.

In this chapter, environmental legislations and national plan are explained that may promote circular economy indirectly. Then, research models proposed by DOE and Ministry of Automotive Association are discussed, followed by case studies of implementation of circular economy at enterprise level. Afterwards, the practice of coprocessing and factors promoting and inhibiting the successful implementation of circular economy are discussed. At the end, the benefits of implementation of circular economy are listed, followed by international collaborations for implementation of circular economy.

2 Legislations

The environmental protection law in Malaysia was introduced in 1974 as Environmental Quality Act (EQA) 1974 (Department of Environment 2018a). Until now, a total of 31 regulations and orders on environmental protection have been ratified since 1974. The initial environmental legislations were focused on protecting environment from pollution originating from palm oil and rubber industry. Then, scheduled waste started to become a major problem, and in 1989 regulation on scheduled waste was enacted. However, after full amendment on 1989 scheduled waste regulation, updated regulations on scheduled waste were passed as legislation in 2005 (Isa 2012). Then in 2007, a second act was introduced on solid waste management pertaining to municipal solid waste. Interestingly, even though Malaysia has several legislations on protecting the environment from pollution, one can contravene it after acquiring a licence. A list of legislations on environmental protection and resource circulation is shown in Fig. 1.

Unlike other Asian countries, i.e. China, Japan and Malaysia do not have any legislation specifically on circular economy. Nevertheless, there are some sections in two environmental acts and in Scheduled Waste Regulation that promote 3R (reduce/reuse, recycle, recover) and can establish the foundation for implementation of circular economy (Table 1). The regulation 7 in Environmental Quality (Scheduled Waste) Regulation 2005 is especially being administered by DOE to promote reuse and recycling of scheduled waste generated from industries. Kualiti Alam is the only licenced scheduled waste management company in peninsula Malaysia that treats and disposes off hazardous waste. But the special management of scheduled waste in this regulation refers to waste management by the unlicenced facilities,

Legislations Related to Environmental Protection and Resource Circulation

- Environmental Quality Act, 1974
- Environmental Quality (Scheduled Waste) Regulation, 2005
- Solid Waste and Public Cleansing Management Act, 2007

Legislations Related to Environmental Protection

- Environmental Quality (Prescribed Premises) (Crude Palm-Oil), 1977
- Environmental Quality (Prescribed Premises) (Raw Natural Rubber), 1978
- Environmental Quality Clean Air Regulations, 1978
- Environmental Quality (Sewage and Industrial Effluents) Regulation, 1979
- Environmental Quality (Control of Lead Concentration in Motor Gasoline) Regulation, 1985
- Environmental Quality (Refrigerant Management) Regulation, 1999
- Environmental Quality (Halon Management) Regulation, 1999
- Environmental Quality (Dioxin and Furan) Regulation, 2004
- Environmental Quality (Industrial Effluent) Regulation, 2009
- Environmental Quality (Control of Pollution From Solid Waste Transfer Station and Landfill) Regulation, 2009
- Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 2015

Fig. 1 Malaysian legislations related to environmental protection and resource circulation

Table 1 Regulations and sections of Malaysian environmental law that promote resource circulation

Legislations	Regulation/section/subsection	Description
Environmental Quality Act 1974	**Section 21** (Power to specify conditions of emission, discharge, etc.)	Minister may set the limits on the emission, discharge or deposit of pollution, hazardous material or waste
	Section 30A (Power to control use of substance and product and to state environmental labelling)	Minister may prescribe a substance to be reduced, recycled, reused or a product to contain a minimum percentage of recycled substance
	Section 51 (Regulations)	Minister may make regulations that are in accordance to Environmental Quality Act 1974
Environmental Quality (Scheduled Waste) Regulation 2005	**Regulation 7** (Application for special management of scheduled wastes)	Waste generator can apply for their scheduled waste treated, disposed of or recovered in premises or facilities other than prescribed premises or facilities
Solid Waste and Public Cleansing Management Act 2007	**Section 101** (Reduction, reuse and recycling of controlled solid waste)	Minister may require reduction, reuse and recycling of controlled solid waste
	Section 102 (Take back system and deposit refund system)	Minister may introduce extended producer responsibility

Source Department of Environment (2018a, b) including the industry itself. Under this regulation, industries have more control over the management of their waste as they can opt for reuse and recycling of scheduled waste, instead of sending it to prescribed facility for final disposal. A detailed discussion on the special management of scheduled waste is elucidated in the discussion and analysis section. Solid Waste and Public Cleansing Management Act, 2007 is directed towards the management of municipal solid waste, construction and demolition waste, agricultural waste, etc. There are sections in the Solid Waste Act that promote resource circulation by implementation of 3R and promote extended producer responsibility. Lastly, Environmental Quality Act 1974 also presents the legal binding of protecting environment from the release or generation of pollutants and waste, respectively. Moreover, section 30A in EQA 1974 also gives the power to the Minister to prescribe the practice of 3R (reduce, reuse and recycle) and/or reduce the consumption of raw material by using the recycled material. Nevertheless, section 30A cannot be enforced until the Minister, after consultation, approves such practices. Hence, no binding legislations related to circular economy have been introduced into the Malaysian environmental law.

Malaysia launched its latest national plan, Eleventh Malaysian Plan, from year 2016 to 2020. In this national plan, a great emphasis has been given on the adaptation of sustainable consumption and production. The national target of MSW recycling is 22% by the end of Eleventh Malaysian Plan. To completely implement sustainable consumption and production, dependency on unrenewable energy sources must decrease while at the same time dependency on renewable energy sources must increase. Malaysia regards wind, geothermal and ocean energy sources as the potential sources. Hence, current national plan aims at research and development on renewable energy sources. The national target of installation of renewable energy capacity is 2080 MW, and consequently, aims at 40% reduction in GHGs emission intensity from gross domestic product (GDP) in comparison with 2005 level. Under the umbrella of Eleventh Malaysian Plan, sustainable consumption and production will be achieved by following the strategies that focus on renewable energy and holistic waste management. Before the introduction of current national plan, waste management had been implemented independently by several agencies such as Department of Environment for scheduled waste, Solid Waste Management and Cleansing Corporation (SWCorp) for municipal solid waste, construction and demolition waste and others. Since the target is to formulate a holistic approach towards waste management including all types of wastes: agriculture, solid, sewage, construction, mining, radioactive and scheduled waste; it is suggested that these agencies would be working together on a shared platform for the successful enforcement of holistic waste management. Moreover, investments on "waste as resource" are planned to increase so that waste could be recycled, reused, reclaimed instead of current method of disposal at landfills (Eleventh Malaysian Plan 2018). It is worth noting that Malaysia has recycling target for MSW only. There are no targets or goals for other types of waste, especially related to hazardous or non-hazardous waste generated from industries. However, the consensus among government agencies is that the larger goal of waste management is to move towards zero waste nation. So, the recycling target for MSW is only the beginning.

In 2009, at the 15th Conference of Parties in Copenhagen, Denmark, Malaysia, voluntarily agreed upon reduction in the emission intensity of GDP by up to 40% by 2020 from 2005 level, and this has been added in the Eleventh Malaysian Plan. Furthermore, the goal of sustainable production and consumption is also aligned with 12th Sustainable Development Goal "Responsible Consumption and Production" as it was incorporated in the national plan. Another international treaty that Malaysia enacted is Basel Convention. There are three main objectives of Basel Convention. Firstly, it aims to reduce hazardous waste generation, in terms of quantity and quality of the hazardousness. Secondly, Basel Convention intends to reduce the movement of hazardous waste internationally, which thus leads to its third objective which is to dispose the hazardous wastes in proximity to the source of the generation of hazardous wastes. Malaysia incorporated Basel Convention in their Scheduled Waste Regulation 2005 to stop the transboundary movement (Isa 2012).

Solid Waste Cooperation (SWCorp) launched the SWCorp Strategic Plan 2014–2020 for the promotion of sustainable solid waste management services in accordance with government's effort for it. This plan is part of the planning of SWCorp to strengthen the solid waste management services and aims towards a clean nation by 2020 through implementation of several strategies. These strategies cover a broad range of aspects relating to public awareness (including awareness on waste to wealth and waste to energy), change in behaviour, sustainability, improving solid waste management facilities and technologies, enforcement of existing legislations and policies, research and development (Mohr and Manaf 2017). This plan also realizes the fact that sustainable solid waste management will only be possible by implementation of circular economy; therefore, all the strategies must work towards the long-term goal of zero waste nation.

When it comes to construction and demolition waste in Malaysia, although there are no legal requirements in practicing resource circulation, a program titled "Construction Industry Transformation Program (CITP)" was initiated by Construction Industry Development Board (CIDB). Under CITP, sustainable development is aimed through several initiatives. The initiative related to resource circulation is "Reduce irresponsible waste during construction", and the target is to utilize 20% of recycled construction and demolition waste (tonnage) by year 2020 from the baseline of 2016 (CITP 2018).

In conclusion, Malaysia is currently lacking an official top-down approach to implement circular economy or resource circulation, unlike China and Japan. Despite the absence of direct legislations on circular economy, the need for resource circulation and sustainable waste management has been realized among the government agencies. Therefore, several initiatives have been taken, and targets have been set until year 2020. Nevertheless, in the absence of explicit regulatory framework on circular economy, becoming a zero waste nation would be nearly impossible for Malaysia.

3 Research Models

The research models described in this section are based on the proposal of the Department of Environment (DOE) on industrial ecology and the proposal of the Malaysian Automotive Association on processing of End-of-Life Vehicles (ELVs). These research models do not represent the basis of CE implementation for all sectors. But, they do provide the realization among Malaysian authorities on potential opportunities in waste to wealth and waste to energy alternatives.

DOE released guidelines on coprocessing of scheduled waste in cement industry on 25 May 2015. A list of scheduled wastes that can be used as raw material or additive is given in the guidelines. Due to Malaysia's heavy reliance on coal-fired power plants, the fly ash and bottom ash are seen as potential raw material. Based on the category of scheduled waste, fly ash and bottom ash, in addition to dross, slag and clinker, are generally the highest amount of waste generated in Malaysia annually. In 2016, 44.2% of total scheduled waste generated was ash/dross/slag/clinker. Moreover, the second highest amount of scheduled waste generated in Malaysia is gypsum (20.2%), followed by heavy metal sludge (13.61%). Therefore, there is a huge potential for coprocessing in cement industry. The list of scheduled wastes required as alternative raw material or additive is given in Table 2. In the guidelines, a criterion is given for selecting the scheduled waste as raw material alternative, additive or fuel source. Depending on the demand, scheduled wastes can be added to different stages of cement manufacturing process (Fig. 2).

Furthermore, DOE is also promoting industrial ecology and a proposal of establishment of industrial ecology of two types of waste, namely abandoned vehicle and bleached earth are discussed here. In bleached earth management, bleaching earth factory, palm oil mill and acetylene manufacturing plant are proposed to exchange the waste (Fig. 3). Bleached earth from bleaching earth factory will be utilized by palm oil mill, and spent bleached earth will be transferred to soil conditioner; whereas, residue gypsum waste will be available for coprocessing as well for soil conditioner. Calcium hydroxide from acetylene manufacturing plant will be utilized by bleaching earth factory in neutralization process.

Table 2 List of scheduled waste generated in Malaysia and its potential use in cement industry

Type of scheduled waste	Potential usage
Castoff copper slag Spent pot linings Castoff garnets	Alternative raw material
Sludges containing one or more metals: lead, chromium, nickel, copper, zinc, aluminium, tin, cadmium, vanadium and beryllium	
Fluoride containing sludges	
Fly ash from coal-based power plant	Cement additive
Gypsum from power plant Gypsum from chemical plant	

Fig. 2 Processes where scheduled waste can be utilized in cement manufacturing process

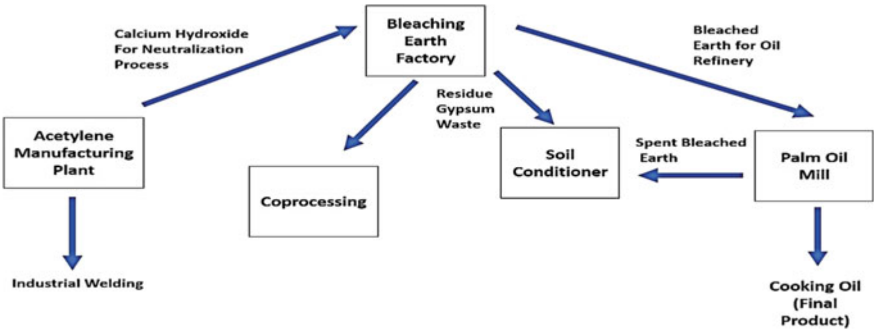

Fig. 3 DOE proposal of industrial ecology for bleached earth plant

In the proposal for abandoned car management, steel manufacturing industry and energy recovery facility are the main facilities that will utilize potential resources from metal recovery and energy recovery from shredded automotive residue (Fig. 4). First abandoned cars will undergo shredding, then plastic and metal will be separated. At this stage, iron will be utilized by steel manufacturing plant, and plastic will be transferred to plastic recovery recycle facility. Shredded automotive residue

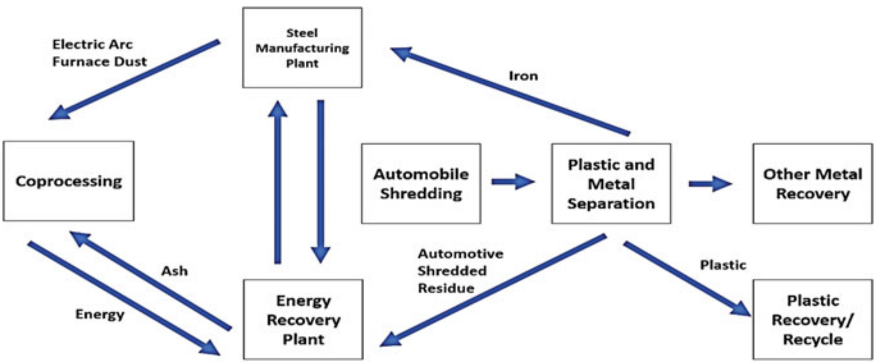

Fig. 4 DOE proposal of industrial ecology for abandoned vehicles

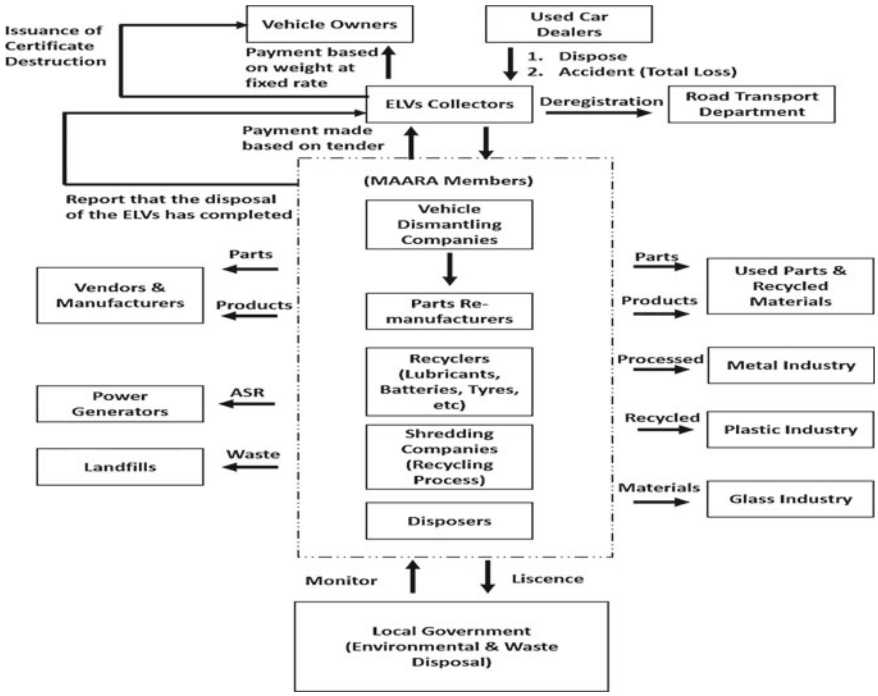

Fig. 5 Proposal of ELVs management (Wong et al. 2018)

will be used for energy recovery. On the other hand, electric arc furnace dust from steel manufacturing plant and ash from energy recovery plant will be available for coprocessing to the requisite industry.

Lastly, a more in-depth proposal was presented by the Malaysian Automotive Association for processing End-of-Life Vehicles (ELV) that is also in line with the proposal of industrial ecology by DOE (Fig. 5). In the proposal of Malaysian Automotive Association, deregistration of vehicles ought to be performed before the dismantling of ELVs. The next step is to acquire the Certificate of Destruction (COD) and to pay depending on the value of fixed scrap imposed by ELV collectors. After the necessary paperwork, under the monitoring of local government (Environmental and Waste Disposals), the procedures starting from disassembling to discarding will be performed by involving parties, such as corporations of vehicle dismantling, parts remanufacturing companies, recycling firms, shredding companies and waste disposing organizations. This is where the implementation of industrial ecology will take place by the participation of several parties, and waste will be incorporated as resource and/or energy resource in several processes depending on the relevant industries. The components of ELVs after dismantling will be reused (that are usable) by vendors and remanufacturers, and ELVs after shredding will be processed and recycled in form of new products (Wong et al. 2018).

The industrial eco park of ELVs management also has the potential of creating industrial symbiosis with construction industries. The proposed concept outlining the ELV processing from automotive to the construction industry revealed the following opportunities of waste exchange. Since ELV processes involve dismantling and shredding, the following materials can be utilized by construction industry after dismantling stage; seats, carpet, plastics and tyres, all of which can be recycled. Whereas, the second stage of ELV processes is shredding. There are two types of shredding processes that are employed, i.e. light and heavy shredding. Depending on the type of shredding carried out, coprocessing can be achieved by following activities: production of raw materials from smelting and refining, creating smelted products from aluminium scraps and recycling (non-metallic residue treatment). The end products of coprocessing will be insulation materials, flooring materials, concrete blocks, foundation, roof tiles, aluminium cladding, composite panels, structural glazing, container buildings, partition walls, windows and interior furniture (Wong et al. 2018).

4 Case Studies

The case studies demonstrated here are based on the implementation of closed-loop initiatives or cleaner production at the enterprise level. However, the implementation of closed-loop initiatives at each enterprise level has resulted in industrial cascade of waste transfer. Hence, instead of sending waste to landfill for final disposal, the waste was sent to respective companies for utilization of waste as resource.

4.1 Oleochemical Processing Plant

As evident in the Eleventh Malaysian Plan, there is a growing realization of sustainable development by balancing the economic and industrial growth in conjunction with environmental preservation and protection, as well as efficient utilization of energy sources. The expansion of oleochemical industries in Malaysia has been contributed by several factors such as the availability of raw materials (palm oil), the fluctuations in petroleum prices, regular animal diseases (which made tallow-based fats unreliable) and the high demand for downstream products such as fatty acids, fatty alcohols and glycerine. Therefore, the expansion of industry has resulted in manufacturing of additional products, i.e. soap noodles, esters, fatty alcohols, oleic acid, etc. Consequently, the expansion of oleochemical industry and the production of downstream products have led to complex waste generation. Wastes generated from oleochemical industry are filter cake, biological sludge, steam condensate, spent nickel catalyst, glycerine pitch, fatty acids residue, wastewater and flue gas.

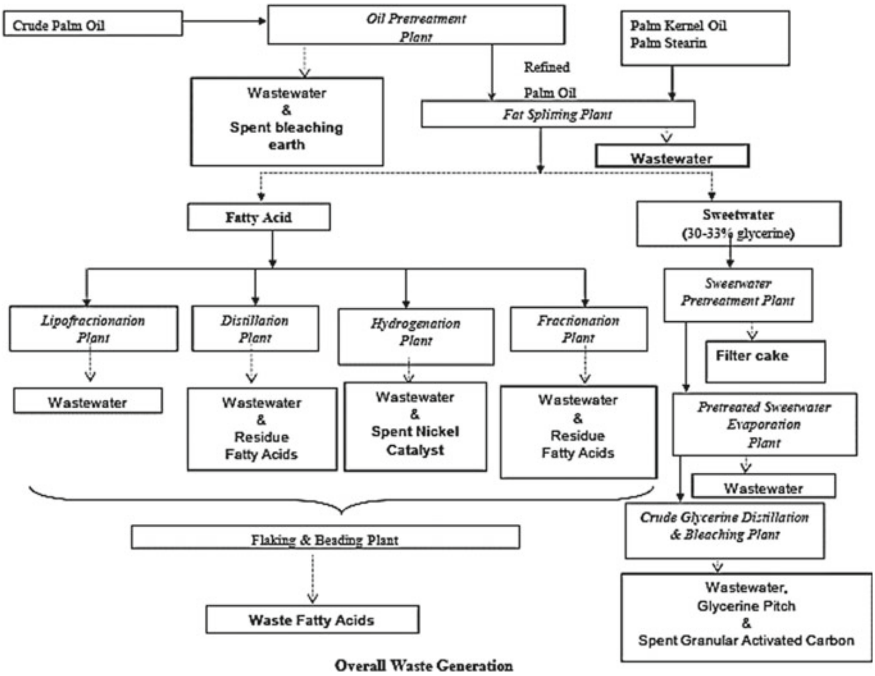

Fig. 6 Processes involved in oleochemical processing plant (Agamuthu 2001)

An example of complex waste generated from oleochemical industry is given here and is based on the source (Agamuthu 2001). The Palm-Oleo Sdn. Bhd. plant processed 364 metric tons of oil daily and in result produced a total of 20 metric tonnes of waste. There were multiple waste streams due to the extensive manufacturing processes (Fig. 6). The oil pre-treatment process generated 2.2 tonnes of spent bleaching earth daily, and after the pre-treatment the oil would go through fat splitting process. Fatty acids from fat splitting process then went through four different processes separately such as lipofractionation, distillation, hydrogenation and fractionation. While residue fatty acid was generated from distillation and fractionation process, 0.17 tonnes spent nickel catalyst was generated from hydrogenation process. Flaking and beading process also resulted in the generation of fatty acid waste. A total of 14.2 tonnes of residue fatty acid was generated from the above-mentioned processes. The pre-treatment of sweetwater generated 0.78 tonnes of filter cake waste. From crude glycerine distillation and bleaching plant, 0.49 tonnes of glycerine pitch and 1.3 tonnes of spent activated carbon were generated, respectively. Wastewater was also produced from all the processes, and a total of 0.62 tonnes of wastewater sludge was generated from the treatment of wastewater. The only scheduled waste generated from manufacturing processes was spent nickel catalyst.

From the oil pre-treatment process, spent bleaching earth was treated by oil extraction process using hexane to remove the oil from the earth material. After the analysis, the ratio of 1:3 (wt:vol) of spent earth to hexane was found to be optimum ratio for oil extraction. Whereas, from distillation and fractionation process, residue fatty acids were recycled back in fat splitting plant to produce sweetwater and split residue fatty acids. While glycerine was manufactured from sweetwater, split residue fatty acids went through hydrogenation and distillation processes to produce 80% of fatty acids and 20% of fatty acid pitch that were sold. Research on methods of managing spent nickel catalyst waste revealed the possibility of reuse of spent nickel catalyst. Therefore, spent nickel catalyst was reused back in the hydrogenation process by taking 15 kg of spent nickel and 5 kg of virgin nickel. Lastly, spent activated carbon was reused for treated wastewater bleaching process. Due to reuse, recycling and reclaiming, the demand for virgin raw materials by the production plant and the quantity of total waste generated were reduced. It also resulted in total savings of RM 1 million a year. After the findings of waste audit and research, the execution of cleaner production led to the practice of 4R (reduce, reuse, recycle, reclaim).

4.2 Acetylene Plant

This Malaysian case study is a good example of industrial cascade and is based on the source (Agamuthu 2001). An acetylene production plant at Sitt Tatt Industrial Gases that produced 2400 m^3 of acetylene from 900 kg of calcium carbide and 6000 L of water daily (Fig. 7). The by-product of acetylene production was generation of carbide sludge which was in slurry form with pH of 12–13. DOE limit of pH is 6–9 and anything below or above this range is considered scheduled waste. So, approximately 3800–4200 tonnes of scheduled waste in the form of carbide sludge were being generated annually. Before the implementation of closed-loop initiative,

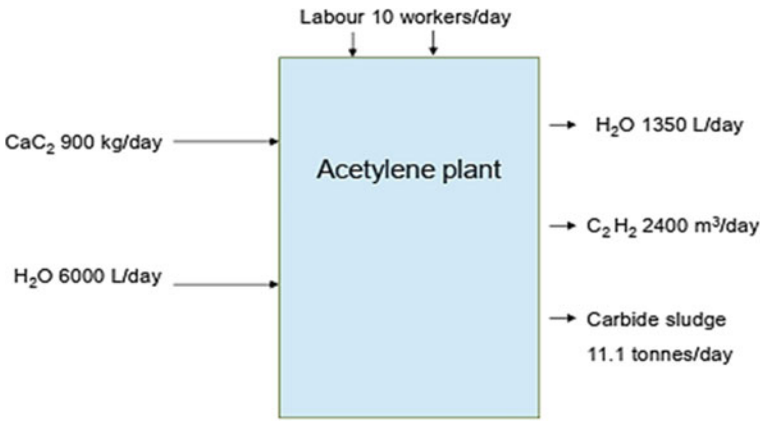

Fig. 7 Mass balance of acetylene manufacturing plant at Sitt Tatt Industrial Gases before the implementation of closed-loop initiative

ponding system was used for sludge treatment. After the treatment, the sludge was sent for final disposal at landfill. However, the treatment of sludge in ponding system turned out to be inefficient as it required greater space for expansion and was an environmental hazard due to potential health hazard to acetylene plant workers. The situation used to get worse in rainy days as sludge would overflow and pollute the surrounding monsoon drains resulting in odour problems.

For reducing waste generation, vacuum filtration was deployed to extract water from the sludge; whereas, flocculation technology was implemented to render carbide slurry as resource for potential buyers. Therefore, by investing RM 1 million in carbide sludge waste treatment and recovery facility, acetylene manufacturing company could save a total of RM 500,000 per year by recycling water and avoiding landfill charges (RM 300,000 by recycling water and RM 200,000 by avoiding landfilling). Moreover, medical expenses were also avoided by 20% (RM 31,000 per year) due to the elimination of health hazards by termination of ponding system for carbide sludge treatment. The treated carbide sludge was sold at RM 1,200 per tonne to another cosmetic manufacturing company that required basic material for neutralization. Hence, it resulted in the income of RM 1 million annually. Therefore, total waste generation was minimized by adopting cleaner technology and cascading waste between two manufacturing industries. Moreover, the implementation of cleaner technology also reduced the intake of freshwater for manufacturing processes.

4.3 Tex Cycle Sdn. Bhd.

Tex Cycle Sdn. Bhd. comes under the Tex Cycle Technology Berhad which is an investment firm for several other companies as well. Tex Cycle Sdn. Bhd. is an ISO 14001 certified company that recycles and recovers scheduled waste in Malaysia. It collects contaminated used rags, wipes, gloves and containers/drums, etc., from various companies. Moreover, Tex Cycle also converts damaged materials into safe recyclable products that are suitable for reuse. It has over 1000 customers from all over Malaysia. The following case study is based on the source (Tex Cycle, n.d.).

Scheduled waste is transported from waste generator to Tex Cycle; then the scheduled waste is weighed and sorted out depending on the type. Afterwards, in the recycling section, contaminated rags/wipes/gloves are washed in industrial washing machines and dried. Then, they are sent to the finishing section where they are folded and packed. From the finishing section, washed materials such as rags, wipes, gloves are either sent back to respective companies for reusing, or sent to recyclers (cleaned rubber material is sent to rubber recyclers) or converted into new coproducts. On the other hand, contaminated containers/drums are washed in the triple rinse washing system and after drying are either sent back to respective companies or to respective recyclers. At the end of the cleaning processes, two types of waste are generated: damaged materials and wastewater. The complete cycle of recycling is shown in Fig. 8.

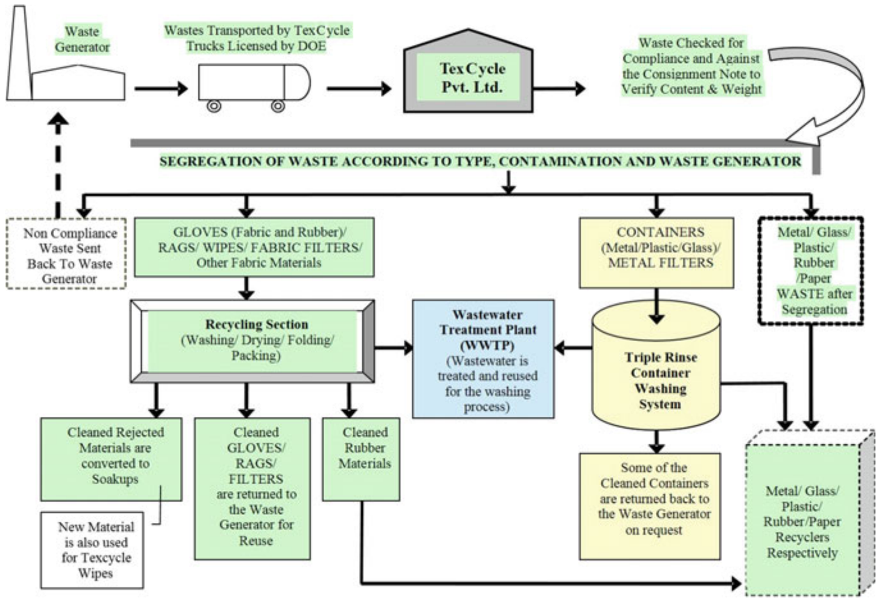

Fig. 8 Flow diagram of processes related to recycling of scheduled waste at Tex Cycle Sdn. Bhd.

Raw wastewater is treated on-site. The main steps in wastewater treatment are electro-coagulation, ozone diffusion (applied in two separated steps) and treatment with UV light, activated carbon as well as reverse osmosis process (Fig. 9). Hence, wastewater is recycled and is reused for the washing step again. Whereas, damaged materials (rags/wipes, etc.) after washing are converted into coproducts such as shoe covers, chemical spillage soak-ups, wipes and floor mats.

The annual savings from reducing freshwater intake by recycling wastewater are RM 63,000. Energy input is also reduced by using solar energy in heating water for washing and for sludge treatment (lime is also added to sludge to reduce the drying time). Additionally, coproducts like Tex Cycle (TC) sorbent bags, wipes are also rented by industries. Their durability is higher than other wipes, hence they last longer. Besides, waste materials are received and additional profit is also gained by Tex Cycle by selling these coproducts to other recyclers.

4.4 Building Construction at University Technology Petronas

Usually, the management of construction and demolition (C&D) waste in Malaysia involves illegal dumping at roadsides; whereas, a minimal quantity of C&D waste is disposed at landfill. Furthermore, the composition of C&D waste generated in Malaysia is shown in Fig. 10. Pertaining to C&D waste, a three-storey office build-

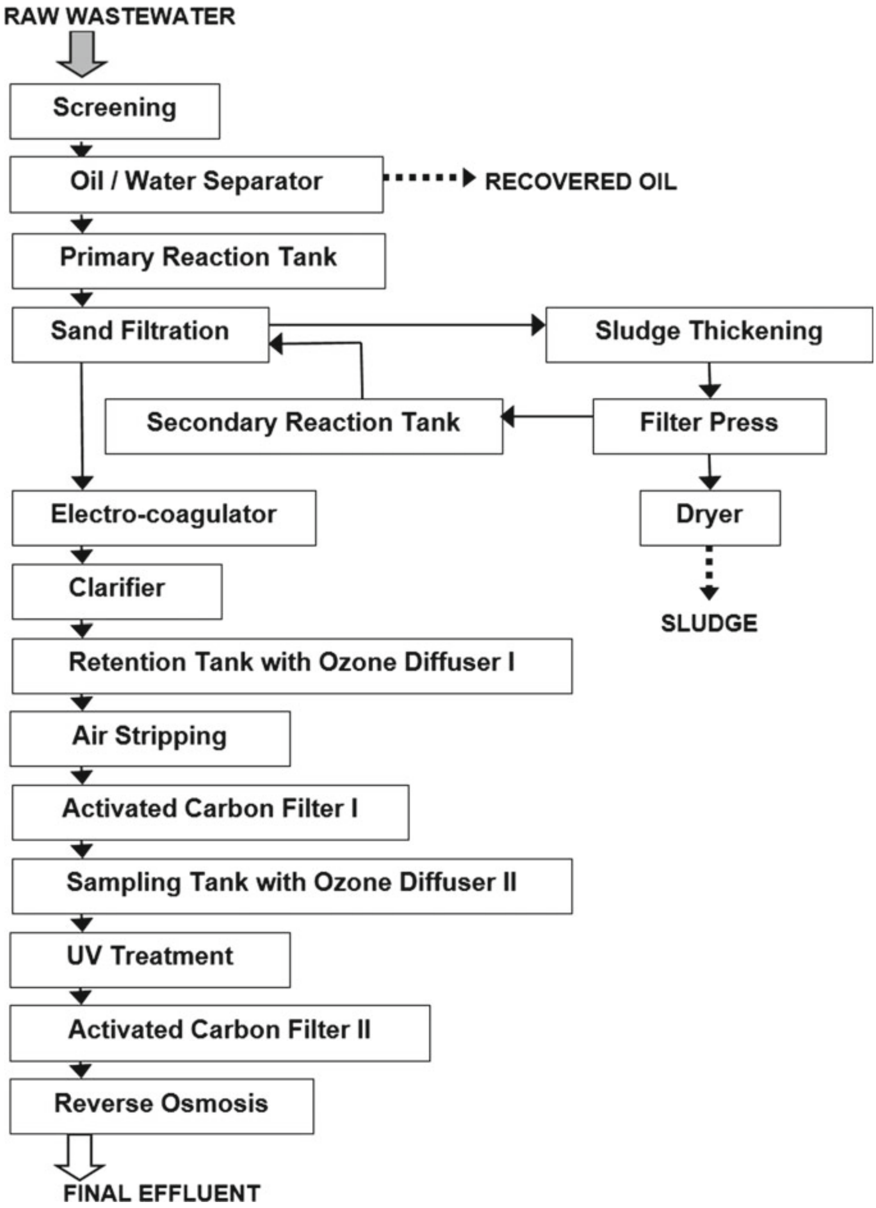

Fig. 9 Wastewater treatment at Tex Cycle Sdn. Bhd

ing was being constructed in the campus of University Technology Petronas that is located in Seri Iskandar, Perak, Malaysia.

This case study, based on the source (Umar et al. 2016), concerns a construction site comprised of 21,225 m^2. The methods taken to reduce operational waste generation were just-in-time approach, site assessment and adequate and secured storage of materials. The construction material was ordered only when it was required; therefore, waste generation from storage of materials for long period of time was avoided. Continuous supervision and assessment of construction site throughout construction further reduced the waste generated as construction activities were supervised. An appropriate and secure storage site was selected on-site to store glass, plasterboards, etc. During construction, recovery of timber offcuts for creating jack studs, noggins and blocking was executed by place makers; whereas, supplier took drainage, plumbing and polystyrene offcuts (resulting from sheathing). Polystyrene offcuts were utilized for recycling.

In addition to the measures taken to avoid waste generation during construction activities, C&D waste generated was recycled and reused (Table 3). Three types of waste were generated from construction of three-storey building, namely timber (74 truck load), metal scraps (5 truck load) and domestic waste (28 truck load). Timber and metal scraps were reused. Hence, 73% of C&D waste was recycled or reused. Assortment of antiseptic wood waste was performed, followed by shredding into woodchips. The potential utilization of these woodchips can be in the form of producing compost and animal bedding, or manufacturing of particleboard, or application as biofilter medium. This is quite an achievement in itself as the general practice of C&W waste management is either illegal dumping or disposal at landfill.

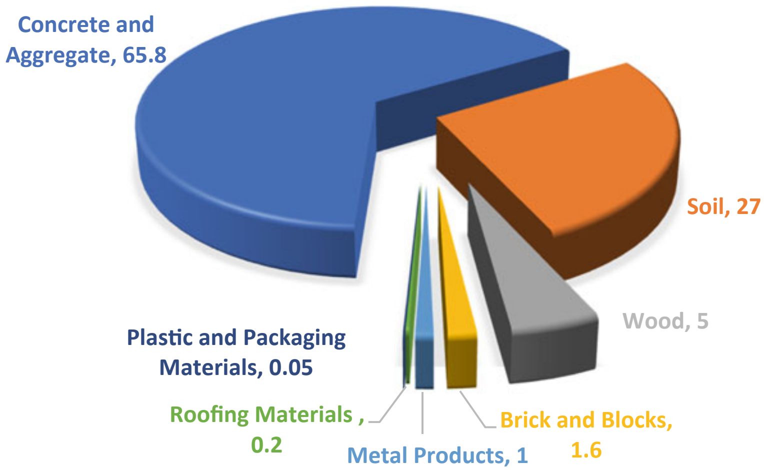

Fig. 10 Composition of construction and demolition waste in Malaysia (Begum et al. 2007)

Table 3 Management of construction and demolition waste generated from construction site at UTP, Perak, Malaysia (Umar et al. 2016)

Type of construction and demolition waste generated	Measure taken
During construction	
Timber offcuts	Reclaimed
Plumbing and drainage offcuts	Taken back by supplier
Polystyrene offcuts	Recycled
At the end of construction	
Timber	Recycled/reused
Metal scraps	Recycled/reused
Domestic waste	Disposed at landfill

5 Discussion and Analysis

There are several reports released by government authorities that provide the latest data on environmental performance. For instance, pollution inventory data including scheduled waste generation is given in Environmental Quality Reports. Based on the Environmental Quality Reports of the last eight years (2009–2016), it is evident that scheduled waste in Malaysia has been managed by several methods such as by prescribed activities that include final disposal in secure landfill or incineration, by recovery and by special management. As mentioned in the legislation section above, under regulation 7 of Environmental Quality (Scheduled Waste) Regulation 2005, Department of Environment Malaysia has been promoting the special management of scheduled waste. The special management referred to is directing the scheduled waste towards unlicenced facilities especially for recycling and reuse. Moreover, special management of scheduled waste by unprescribed facilities also practises the treatment of hazardous waste to render it unhazardous and eventually disposed at sanitary landfill. The management of scheduled waste by prescribed facilities is strikingly less compared to other waste management options (Fig. 11).

Since 2010, approximately 50% of scheduled waste generated has been approved contingently for handling under special management. Whereas, the second most practiced approach is recovery of waste at local and foreign facilities. In 2016, 28% of scheduled waste generated was reused after going through special management. The amount of scheduled waste reused has been approximately above 20% for the last seven years (2010–2016), except for year 2010 when it was 19.7% (Fig. 12). Majority of the scheduled waste that is reused is fly ash and bottom ash generated by industry and coal-fired power plant. While fly ash and bottom ash have been utilized by cement manufacturing industries in Malaysia, other scheduled waste such as heavy metal sludge, mineral sludge, gypsum, spent mixed oil, glue, contaminated active carbon and petroleum by-products are reused back by the respective companies that generate these scheduled wastes. On the other hand, the amount of scheduled waste recovered at local and foreign facilities has been variable for the last eight years (2009–2016). The highest amount of waste sent for recovery was 40.4% in 2009,

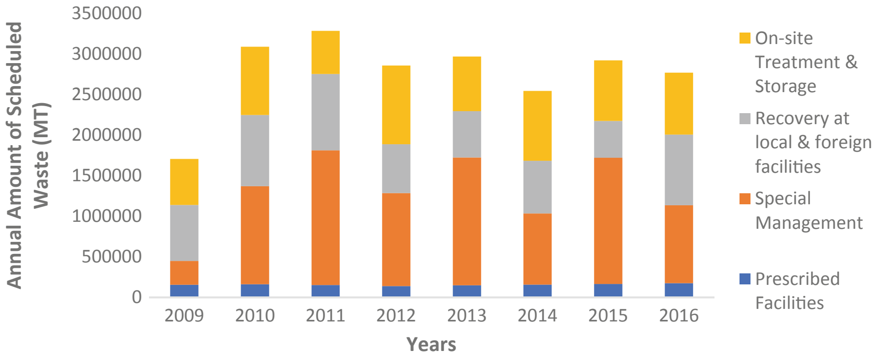

Fig. 11 Management of scheduled waste generated in Malaysia annually from 2009 to 2016 (Environmental Quality Report)

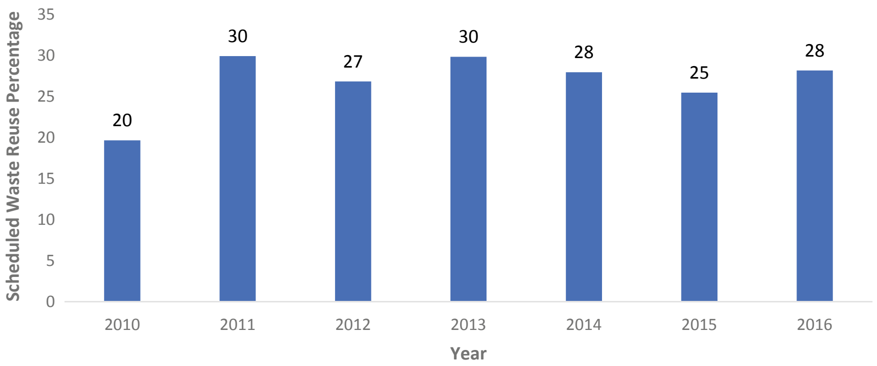

Fig. 12 Total percentage of scheduled waste reused under special management (Environmental Quality Report)

and the lowest amount of waste sent for recovery was 15.5% in 2015 (Fig. 13). In 2010, out of 1,206,568.31 metric tonnes of scheduled waste managed under the special waste management, 50.34% was reused as raw material in industries and the rest (49.64%) was emplaced at approved sanitary landfill. It is evident that even in the absence of legislations for circular economy.

Eleventh Malaysian Plan, another government document, reported the success of Tenth Malaysian Plan in implementation of 3R (reuse, reduce and recycle) program as domestic recycling rate increased from 5.0 to 10.5% in just two years (2010–2012). It was the result of intensified efforts in achieving the recycling targets of Tenth Malaysian plan. Consequently in 2013, National Biomass Strategy 2020 was initiated to abet waste to wealth initiatives by assessing the opportunities for developing new industries in Malaysia that will yield high-value products (exportable) from agricultural biomass waste. Currently, power is generated using palm oil biomass pellets. Another outcome of the Tenth Malaysian plan was reduction in GHGs emission due

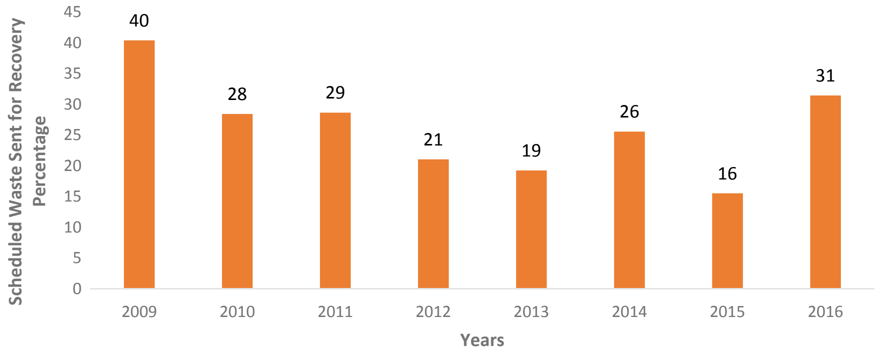

Fig. 13 Total percentage of scheduled waste recovered (Environmental Quality Report)

to waste management initiatives taken. Since 2013, GHGs emission of 33.1 million t CO_2eq and 4 million t CO_2eq were avoided by energy recovery from empty palm oil fruit bunches and by activities involving paper recycling, respectively (Eleventh Malaysian Plan 2018).

As highlighted in the Tenth Malaysian Plan, Malaysia generates the plethora of biomass. There have been many studies by Malaysian scholars that propose sustainable utilization of biomass waste for producing bioproducts to achieve circular green economy. While palm oil industry continues to contribute to the gross national income in Malaysia, a single tonne of crude palm oil results in nine tonnes of biomass. Currently, local industries are focused on the production that attract subsidies, i.e. bioenergy, feed-in-tariff, biogas, etc. Similarly, prevailing exploitation of biomass also yields biofertilizer, pellets, dried long fibre and biogas. Thus, coproduction from biomass is envisioned for bio-based products, polymers, pharmaceutical and food ingredients, fine, specialty and platform chemicals, as well as bioenergy and biofuel for sustainable production. Additionally, it will also reduce the dependency on fossil fuel. The recovery of recyclable, high-value chemical such as levulinic acid, electricity, metal, biofertilizer and fuel from urban or municipal solid waste could be achieved due to prominent innovative biorefinery configurations from establishment of integrated processes. Extracting only 5 wt% of levulinic acid from waste feedstock increases the profitability by 1.5-fold, thus eradicating the requirement for subsidies such as gate fees paid by local authority to waste processor (Sadhukhana et al. 2018).

Another source of biomass waste generation in Malaysia is organic food waste. The daily generation of food waste in Malaysia is 15,000 tonnes, out of which 3000 tonnes are appropriate for consumption (Malaysians waste 2016). Such a quantity corresponds to 1.5 million bags of 10 kg rice, which would be appropriate for feeding 7.5 million people every day (The Bigger Battle, n.d.). This food waste not only diminishes the chances of human consumption but also increases the pressure on food production. If the current rate of food consumption and generation of food waste is continued, then at least 70% of global food production needs to increase by 2050 (How to Feed, n.d.). Generally, the global trend has been such that the food suppliers are the developing countries and consumers are the developed countries. Therefore, to meet the expected demand of global population, projected to proliferate by 34% in 2050, an investment of $83 billion in agriculture of emergent nations is required yearly for the 32 years. Hence, policy making is the focal point for funding resource-efficient technologies for the economy of developing nations (Sadhukhan et al. 2018).

The transport sector in Malaysia contributes the most to global warming potential (GWP). Yet, biofuel blending can reduce the impacts of transport sector on GWP. While there is still time for conventionalizing the electric vehicle, provisional support for the research and development of biofuel could deaccelerate GWP impact of transport sector. It can be achieved by crude palm oil (CPO) upgradation for manufacturing the drop-in biofuel in compliance with the Roundtable of Sustainable Palm Oil (RSPO) standard and by modification of subsisting fermentation to get butanol. The efficiency of butanol is higher than bioethanol and could be utilized 100% in predominant engine, in addition to integration of gas clean-up technology in prevalent AD system for the production of compressed natural gas (CNG). However, the ultimate emphasis must be on resource recovery from waste (RRfW), carbon dioxide reduction (CDR) and carbon capture and reuse (CCR) integrated biorefineries for additional extraction of resources such that absolute recovery or reclamation is achieved from waste (Sadhukhan et al. 2018).

Unlike European Union and Japan, Malaysia also does not have regulatory framework for ELVs. However, a new proposal of procedural outline is unveiled for local ELV recycling establishments as discussed earlier in the chapter. It is hoped that the framework will provide an alternative in acquiring raw materials in an environmentally sound manner and will increase resource circulation. Therefore, the findings of the research can be used to develop a platform for coprocessing between ELV recycling industry and construction manufacturing industry. Further research on reusability and recyclability of product could offer many prospects for circular economy in construction (Wong et al. 2018). A similar initiative has been proposed by DOE for establishing industrial ecology around ELVs.

A significant contribution to the national economy and the development of necessary infrastructure has been made by construction industry in Malaysia. Regrettably, this important industry also produces one of the single largest waste streams in the country. Segregation at source or practice of 3R, as well as disposal of C&D waste in landfills is not widely practised by majority of the contractors. Additionally, correct handling, storing and transportation of construction wastes are also the responsibilities of the contractor. Yet, significant amount of C&D waste is generated due to inadequate knowledge or experience of contractor, excessive purchasing of materials beyond requirement, inapt storage (resulting in damages to raw material) and reworking. Absence of regulations and guidelines for construction industry and subsequent enforcement contribute to the construction of waste generation (Ikau et al. 2016). At present, collection rate of C&D waste is 15%, whereas the remaining 85% is left uncollected (Aiming for Zero 2015). On the other hand, a total of 851 illegal dumpsites in Malaysia were identified by the roadside in 2015 (Mah et al. 2018). However, despite the mismanagement of C&D waste, the current practice of disposal at open dumps or in landfills is not a sustainable mean of handling increasing C&D waste (Fauziah and Agamuthu 2003) As mentioned earlier, a five-year plan named CITP initiated by Construction Industry Development Board (CIDB) targets 20% recycling of construction waste and to also reduce the generation of irresponsible waste because construction waste can be resold or recycled. For instance, bricks, doors, lighting fixtures and stairway banisters can be resold; whereas, glass can be recycled into fibreglass or used in place of sand for paving and asphalt can be reused by turning it back into aggregate (Aiming for Zero 2015). Therefore, the only way to sustainable management of construction waste in Malaysia is the implementation of circular economy in construction industry via closed-loop initiatives, industrial symbiosis or cascading.

Malaysian Investment Development Authority (MIDA) launched an incentive for establishment of Waste Eco Park (WEP) in 2016. Conceptually, Waste Eco Park encourages industries to recycle and/or recover waste, besides treatment activities and targets sustainable waste management by encouraging corporations to invest in facilities and infrastructure that will manage waste holistically as proposed in the Eleventh Malaysian Plan. The functioning of Waste Eco Park will involve WEP developers: the party who will be responsible for the necessary infrastructure establishment and will be main stakeholder for ensuring holistic waste management inside Waste Eco Park, WEP managers; designated by WEP developer who will assure efficacious coordination, execution and operation of Waste Eco Park and WEP operators; who will partake in holistic waste management and realize national target of reduction in waste disposal, by promoting recovery and increasing recycling of waste, in addition to sustenance of waste management ecosystem (MIDA 2018). Unfortunately, WEP has not been established till date.

It is evident that Malaysian waste management authorities have realized that landfilling is not the long-term solution for sustainable waste management. Even though, developing nations are currently reaping the economic benefits of linear economy, it is also clear that linear economy approach will not last long as natural resources are finite and remediation costs of environmental damage will continue to increase to a point that it will surpass the economic gains. Therefore, the longevity of economic development cannot be sustained without resource circulation by implementation of circular economy. Malaysian authorities have acknowledged the need of sustainable production and consumption by incorporating it in the Eleventh Malaysian Plan and by launching initiatives to promote 3R in the waste management. However, Malaysia is being hindered by the lack of direct regulatory framework on circular economy and consequently the lack of eventual enforcement of legislations. If there is one thing to be learnt from China's successful administration of circular economy, it is the process of reaching towards the goal of circular economy and the most significant top-down and bottom-up approach. Top-down approach is warranted by legal schemes. In China, these regulatory requirements were set by Circular Economy Promotion Law, by Circular Economy Pilot Demonstrations program and the Eco-industrial Park program founded by various government agencies. On the other hand, bottom-up approach is taken by individual enterprises, industries that take part in eco-industrial enterprises to embrace the idea of circular economy. This acceptance of circular economy idea happens when these ideas make financial sense to enterprises due to changing dynamics of market triggered by high prices of energy and resources and deregulation of market entry. Since 1970s, Chinese industries have been adopting bottom-up approach (Mathews and Tan 2011). Malaysia does not have explicit top-down and bottom-up approaches till date. But, there are attempts to implement resource circulation in Malaysia in the form of promotion of regulation 7 of Environmental Quality (Scheduled Waste) Regulation 2005 by DOE, or the programs initiated by SWCorp, CIDB and MIDA, respectively. There are also tax incentives on green technology that can encourage resource circulation. Despite the absence of specific regulations on circular economy, it can be said that there has been uncoordinated implementation of top-down approach by several government authorities as well as bottom-up approaches by individual enterprises as shown in the case studies.

6 The Benefits of Circular Economy

As circular economy is not implemented at national or municipal level in Malaysia, the benefits of circular economy are only confined to the enterprises that are practicing circular economy at enterprises. Due to the implementation of circular economy at firm level, the impact on GDP is not significant.

Based on the case studies described in this chapter, the following benefits were availed:

1. Reduction in resource consumption
2. Reduction in waste generation
3. Economic benefit
4. Reduction in energy consumption
5. Environmental Protection.

Table 4 gives the summary of benefits attained from the implementation of closed-loop initiatives at respective firms in case studies. The benefits of circular economy are interrelated. For instance, the reduction in resource consumption was achieved by recycling and reusing wastes, including wastewater, as raw material in the manufacturing processes. It led to total reduction in waste generation as well, since waste was being incorporated in the manufacturing processes instead of disposal at landfill. Both reduction in resource consumption and reduction in waste generation not only saved expenditures of acquiring raw material and landfilling, respectively, but in some cases also generated extra revenue by selling waste to potential buyers or producing coproducts from waste. Circular economy will not be completely zero waste until energy source is also renewable. Therefore, as shown in Tex Cycle Sdn. Bhd., using solar energy reduced the intake of electricity from local electric grid. Lastly, by adopting circular economy, environment is also protected from pollution of waste, especially scheduled waste, i.e. spent nickel or highly basic carbide sludge and by avoiding extraneous extracting of raw material from the environment.

Table 4 Summary of benefits of implementation of circular economy

Benefits	Oleochemical plant	Acetylene manufacturing plant	Tex Cycle Sdn. Bhd.	Construction site at UTP
Reduction in resource consumption	Reuse of earth material, fatty acid residue and spent nickel	Water is recycled within plant. Carbide sludge is used as resource in cosmetic manufacturing company	Reusing water and producing coproducts from damaged materials	C&D waste was recycled and reused resulting in reduction in consumption of wood and metal resources
Reduction in waste generation	Waste generation is only reduced to sludge	Neither wastewater is produced nor carbide sludge	Waste generation is only reduced to sludge	73% of waste generation was reduced
Economic benefit	Annual savings of RM 1 million	Annual savings of RM 500,000 and annual income of RM 1 million	Annual savings of RM 63,000	Not given
Environmental protection	Yes	Yes	Yes	Yes

7 Collaboration with Other Countries

In 1996, under the Danish Cooperation for Environment and Development (DANCED), several projects introduced the implementation of circular economy at firm level or cleaner production in Malaysia for the first time. Standards and Industrial Research Institute of Malaysia (SIRIM) under the Ministry of Science, Technology and Innovation (MOSTI) employed a technical cooperation programme between the Government of Malaysia and the Government of Denmark. These projects were promoting cleaner production through environmental and energy audits, demonstration sites and the dissemination of information via two platforms, namely Cleaner Technology Extension Services (CTES) and the Cleaner Technology Information Service (CTIS) (Yusup et al. 2015).

Although still in the planning stage, a concept of industrial symbiosis in rubber manufacturing industries was developed in 2008. This industrial symbiosis is a collaboration between Malaysia and Thailand to form a rubber city in Kedah, Malaysia (Kedah Rubber City, n.d.). Potential industrial symbiosis is proposed in a study by Sharib and Halog (2017) as shown in Table 5. Therefore, implementation of circular economy at municipal level in Malaysia is at planning stages that is being collaborated with Thailand.

In order to achieve the commitment of reducing carbon footprint, Malaysia is planning to utilize biodiesel blends in its transportation sector. To accomplish this

Table 5 Proposal of industrial symbiosis in rubber city, Kedah, Malaysia (adopted from Sharib and Halog 2017)

Waste	Waste generator	Annual quantity	Potential usage of waste	Industrial symbiosis
Ammonia Nitrogen	Rubber block process	9,880 kg	Ammonia waste	Conversion into fertilizer
Total solid waste		70,720 kg	Rubber crumb filler or polymer asphalt	Cement concrete indus-try/polymer asphalt binder
Rubber waste	Tyre production	988 kg	Rubber crumb	Cement concrete industry or polymer asphalt binder
Wastewater from cooling system		2,198,716 kg	Recycle water	Feed-in cooling water system
Rejected glove pieces	Glove manufacturer	530,660 pieces	Rubber latex converted into powder form	Incorporation into rubber filler
Sludge or rubber traps		6727.80 kg	Rubber waste latex into carpet backing	Incorporated into carpet backing
Methane	Wastewater integrated facilities	Not available	Methane recovery	Feed-in natural gas used for glove manufacturing
Treated effluent			Biofertilizer	Fertilizer company
Biomass wastes and residues	Cogeneration electricity	Not available	Production of heat and electricity	Feed-in electricity generation for the industries in Rubber City

target, Malaysia had collaborated with Japan for the implementation of biofuels in Malaysian transport sector. A collaborating initiative between Malaysia and Japan was validated in April 2010 for environment and energy. Moreover in 2008, Yanmar, a private Japanese firm, made an investment in a Malaysian research facility specialized in biodiesel, for carrying out research and analytical work for biodiesel fuel that had started industrial cooperation in biofuels between Japan and Malaysia (Lim and Lee et al. 2012). At present, Malaysia's intention of 10% biodiesel blend by 1 January 2017 had been delayed. Therefore, Malaysia is blending 7% of biodiesel. The delay has been due to the lack of subsidy support and the high price of feedstock compared to low prices of petroleum prices. On the other hand, the Eleventh Malaysia Plan aims at 15% biodiesel blend in transport sector by 2020 (Biofuels Annual 2017). In order to implement circular economy sustainably, dependence on renewable energy sources need to increase gradually to a point of complete phasing out of non-renewable energy sources. Thus, Government of Malaysia must continue promotion of biodiesel blends.

8 Conclusion

Malaysia does not have a legal framework on the implementation of circular economy like other nations, i.e. China, Japan and Germany. However, there are certain sections in Environmental Quality Act 1974, Solid Waste and Public Cleansing Management Act 2007 and regulation 7 in Environmental Quality (Scheduled Waste) Regulation 2005 that promote the practice of resource circulation. Malaysia incorporated sustainable production and consumption in the Eleventh Malaysian Plan and aims to take holistic approach towards national waste management. Under the umbrella of the Eleventh Malaysian Plan, Malaysia targets to reduce 40% of GHGs emission intensity from GDP compared to 2005 level and reach 22% of recycling of MSW with a long-term goal of becoming zero waste nation. Additionally, SWCorp launched SWCorp Strategic Plan from 2014 to 2020 to promote sustainable solid waste management services, and CIDB initiated CITP that has a target of incorporating 20% of recycled construction and demolition waste (tonnage) by year 2020 from the baseline of 2016.

DOE has released guidelines on coprocessing of scheduled waste in cement manufacturing industry. Apart from coprocessing in cement manufacturing industry where waste exchange is being practised in all nine plants, research models on industrial ecology are at proposal stages only as they have not been implemented. Furthermore, DOE has also put forward proposals on industrial ecology involving bleaching earth factory and abandoned car management. Lastly, Malaysian Automotive Association presented the proposal on the processing of End-of-Life Vehicles (ELVs) that can lead to coprocessing with construction industry. DOE is also promoting coprocessing under the regulation 7 of Environmental Quality (Scheduled Waste) Regulation 2005 where scheduled waste undergoing "special management" is reused and recycled. Moreover, recovery from scheduled waste is also practised at local and foreign facilities.

Several opportunities of sustainable waste management and resource circulation have been highlighted by the research findings.

i. The generation of biomass in Malaysia is extremely high; therefore, it is proposed that in addition to waste to energy approach applied to biomass, bioproducts can also be produced. It is envisioned that coproduction of bio-based products from biomass will be carried out resulting in outputs such as fine, specialty and platform chemicals, food and pharmaceutical ingredients, polymers, together with biofuel and bioenergy.
ii. Biofuel production and its usage in national transport sector can help decouple the economic development from GWP. The recommended routes for production

of biofuel are crude palm oil (CPO) upgradation for yielding drop-in biofuel, in compliance with the Roundtable of Sustainable Palm Oil (RSPO) standard, reconstructing current fermentation to attain butanol. The efficiency of butanol is higher than bioethanol and can be used completely in predominant engine. Moreover, by incorporating gas clean-up technology in existing AD system, CNG could also be produced.

iii. A processing framework of ELVs is proposed that will provide substitute for acquiring raw materials in an environmentally sound manner, hence will increase resource circulation. The findings of the research can be used to develop a platform for coprocessing between ELV recycling industry and construction manufacturing industry.

Establishment of Waste Eco Park program by MIDA promotes recycling and recovery of waste, in addition to treatment activities and aims to achieve sustainable waste management by encouraging investments in facilities and infrastructure towards said goals that are also aligned with the Eleventh Malaysian Plan.

In order to successfully implement the circular economy, top-down and bottom-up approach is required. While, Malaysia does not have explicit top-down and bottom-up approaches till date, there have been attempts to implement resource circulation in Malaysia as top-down approach in form of promoting regulation 7 of Environmental Quality (Scheduled Waste) Regulation 2005, by DOE, or the programs initiated by SWCorp, CIDB and MIDA. There are also tax incentives on green technology that eventually improves resource circulation.

The case studies presented manifest the practice of circular economy at enterprise level that imply the willingness of some firms to take part in bottom-up approach. The benefits of implementation of circular economy at enterprise level are reduction in resource consumption, reduction in generation of waste, protection of environment and human health, reduction in energy consumption, cost savings by reusing or recycling the waste and additional profit gain by selling waste to potential industries.

International collaboration in the implementation of circular economy started with cooperation with Denmark in 1996 where cleaner production was employed in several companies. Malaysia's collaboration with Japan in biodiesel blends started in 2008, and Malaysia aims to blend 15% of biodiesel by 2020. Lastly, rubber city in Kedah, Malaysia, is at planning stage where Malaysia will cooperate with Thailand to implement industrial symbiosis.

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