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Multi-criteria decision approach with stakeholders for food waste management

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Abstract. The activities related to agri-food production and the disposal of its waste account for a large number of greenhouse gas emissions. In many cases, food waste (FW) management is established by making a single assessment for its sustainability based on economical or environmental impacts. However, social impact assessments on stakeholders are often incomplete or missing, and its efficiency is seldom measured. Decision-making in waste management strategies, such as the acquisition of appropriate waste treatment sites or methods used, frequently involves multiple stakeholders such as government, municipalities, industries, experts, or public sectors. Due to the complication of differing criteria and alternatives in FW management technology, a multi-criteria decision-making (MCDM) methodology is recommended to certify the quality of the decision-making process. This paper reviews the use of MCDM as decision supporting techniques in modelling and analysing decision making in situations with multiple stakeholders for FW management. The synthesis results obtained through the MCDM tool will be more reliable when requesting confirmation from stakeholders based on a recommended minimum range of criteria for each sustainability dimension in the FW issues. Finally, potential studies in this area have been proposed.

1. Introduction

The deviation of agri-food commodities to waste is indicated as the deficiency of resources in terms of labour, peats and seeds, freshwater, and cropland; additionally, the justified losses recorded for croplands, freshwater, and fertilizers have been estimated to be 23% of the total cropland area (31×10^{-3} ha/cap/yr.), 24% for total crop freshwater consumed (27 m^3/cap/yr.), and 23% of total global fertilizer used (4.3 kg/cap/yr.), respectively [1]. Besides resource losses, [2] claimed that agri-food waste (FW) often creates the opportunity for raised greenhouse gas (GHG) productions that are environmentally hazardous and liable with the degradation of the ozone layer. It has also been acknowledged that agri-food production and waste disposal practices contribute to many GHG emissions, for average 19% -29% of overall emissions [3]. It emits 9800-16,900 mega metric tonnes of carbon dioxide (CO_2) equivalent. The involvement of agri-FW in municipal solid waste (MSW) promotes then accelerates the amount of CO_2 and methane (CH_4) discharges [4-5].

Owing to enormous losses of resources in global food systems and the impacts of waste disposal on climate change, greater focus needs to be placed on FW elimination. Besides, proactive assessment on the climate impact of its waste management (WM) should be conducted. Several of the recent research on environmental impacts on WM technologies for FW have been identified and often contrasted, for example, with landfill, incineration, composting, and anaerobic digestion (AD) [6]; some researchers have recognized the positive consequences of FW prevention. For example, [7] found that the FW stream could have been reduced to 20%, however, did not indicate the forms in which it might be reduced, or the recognition of multi-stakeholder participation in determining proper waste treatment locations or technologies used, that involves local and regional authorities, WM practitioners, ecologists, residents, retail operators, and food associated sectors (both small and large). The process of recognizing, compiling, and harmonizing the views and ideas of multiple stakeholders is a problematic task and generally calls on issues related to multi-stakeholder preferences which can lead to serious conflicts of interest and mistaken assumptions, particularly by positioning their significance, need, and importance in correlation with treatment techniques [8].

Thus, multi-criteria decision-making (MCDM) is a system for promoting decision-making that can identify and analyse several overlapping decision-making factors for the management of organic waste. By using MCDM, it is possible to propose two or more unique viewpoints or alternative perspectives based on the four main aspects (environmental, financial, social, and technical) to achieve the evaluation objective. This review extensively examines several decision-making assessment steps in selecting between the different solutions to the WM problem focusing on techniques of MCDM. Although the majority of MCDMs in WM models consider the environmental and economic aspects [9-10], relatively few consider the social and technological aspects. The four requirements (environmental, financial, social, and technical) must be assessed [8], to ensure the viability of the decision-making support system for management technology for FW [11-12]. This review would suggest a minimum collection of criteria for each sustainability dimension of WM problems and further views on potential studies in this area have been proposed. It will enable policymakers to establish effective policies for the sustainable management of agro-FWs.

2. A multi-criteria decision-making in food waste management

Table 1 shows a summarization of MCDM in FW management and the engagement with stakeholders for the decision-making process through the analysis of previous research journals and reports relating to FW. Various alternatives have been established concerning treatment technologies for FW management, such as the landfill, incineration, composting, and AD method. The following four stages are widely used to build the MCDM model; (i) Determine the work objective, (ii) Defining the theoretical framework, (iii) Determining the relevant criteria, sub-criteria, and possible solutions or alternatives, and (iv) Data collection and data processing [8]. Each MCDM tool uses a specific technique to perform a pairwise comparison [8-10]. The analysis of data may be viewed as a ranking of criteria according to their significance. Experts, policymakers, and other stakeholders will serve as evaluators. The numerical values shall be used to reflect the weight or degree of significance of each criterion [11].

2.1. Multi stakeholder

The diverse stakeholder community has various favourable treatments; therefore, it is impossible to find a consensus. It appears that a simplified resolution was introduced by scientific community (Table 1) in which the governments or municipalities stakeholders' groups and experts were granted priority instead of the public or the citizens. It was consequently needed to collect appropriate input from stakeholders and was considered necessary to ensure that panellists were mindful of the implications on the climate, for example, the procedure for determining and weighing the impact categories of present studies. Conversely, [24], who surveyed 11 of Europe's leading MSW programs in nine countries, strongly advocated the inclusion of various public groups in the decision-making process from the very beginning, with the hope that it may reduce the risk of increasing conflict and public opposition surrounding MSW projects. This idea was supported by several studies such as in [21-23] which demonstrated the involvement of local residents as decision makers. [21-23] invited multiple stakeholders from diverse fields of expertise to respond to surveys on weighting factors and they include policymakers, specialists, environmentalists, residents, and professionals.

Table 1. MCDM in FW management with multi stakeholder's engagement as decision maker.

Reference	MCDM steps				[a]Consulted stakeholders					Stakeholders' relationship	
	Methods	Aspect	Weight	Evaluation	Government or municipality	Public or residents	Experts	Business	NGOs/ Other organizations	Hierarchy	[b]Co
[8]	AHP	√	√	√	√		√			√	
[10]	AHP	√	√	√	√		√		√	√	√
[13]	AHP	√	√	√	√		√			√	
[14]	AHP	√	√	√			√			√	
[15]	MCDM	√		√	√		√		√		
[16]	AHP	√	√	√	√		√		√	√	
[17]	TOPSIS/ PROMETHEE/ FUZZY TOPSIS	√	√	√			√			√	
[18]	PROMETHEE	√	√	√			√			√	
[19]	AHP/ASPID	√	√	√	√		√			√	
[20]	ELECTREE III	√	√	√	√		√		√		
[21]	Fuzzy AHP + CAM	√	√	√	√		√	√	√	√	√
[22]	AHP + TOPSIS	√	√	√	√	√	√	√	√	√	√
[23]	AHP+LCA	√	√	√	√	√	√	√	√	√	√

AHP: Analytical Hierarchy Process; MCDM: Multi Criteria Decision Making; TOPSIS: Technique for Order Preference by Similarity to Ideal Solution; PROMETHEE: Preference Ranking Organization Method for Enrichment Evaluation; ASPID: Analysis and Synthesis of Parameters Under Information Deficiency; ELECTRE III: Elimination and Choice Translating Reality; VIKOR:VIseKriterijumska Optimizacija I Kompromisno Resenje(Multicriteria Optimization and Compromise Solution); CAM: Consensus Analysis Model; [b]Coalition: Stakeholders in waste problems can generally divided into the government sector, experts, NGO's and business. Each stakeholder category also normally contains several members. For e.g., an NGO may be a coalition of several environmental protection groups, related associations, etc. (Hung et al. 2007).

2.2. Criteria and sub-criteria

Table 2 shows a simplified set of criteria and sub-criteria as a basis of assessment for selecting a suitable FW management technology. Based on 20 studies involving frequency of use reviewed, it would seem that the environmental aspect is the main and most important approach for this context, suggesting a more analytical or philosophical target. In this case, the MCDM is used to advise decision-makers about the environmentally advantageous options or policy-making groups to better forecast multiple choices for the management of biodegradable waste in a given region. The least of these are the main technical requirements for just around four reports. Alternative criteria and sub-criteria could be identified from a broad variety of references, including field experts, publications and secondary - information [16].

2.2.1. Environmental aspects. Environmental impacts refer to the condition in which the level the environmental system is disrupted by anthropogenic activities. It is very important to verify the *environ*-mental impacts for protecting public health, natural resources, and environmental sustainability. According to Table 2, there are five main dimensions or sub criteria in environmental impacts namely resources-energy requirements /abiotic depletion, emissions of GHG, land use, water pollution and air pollution. The integration of these five dimensions has been widely recognized by the research community of sustainability.

2.2.2. Economy aspects. Economic impacts are related to the costs and benefits needed to use the technology. There are four main dimensions in economic impacts namely investment/capital cost, operational /maintenance cost, revenues/income and resource recovery (Table 2). Investment costs shall include all costs related to procurement of technical equipment, technical installations, construction of roads and national grid links, maintenance services and building works. Operational/maintenance costs are the costs required mostly during the composting period. Revenues could be collected from the sale of by products: energy, heat, compost and recycled materials. Finally, resource recovery is related to energy recovery and material recovery such as valuable bio fertilizers for farming utilizations.

2.2.3. Social aspects. The socio-cultural impacts are essential to the improvisation of working environments, profits and access to social resources. There are five main dimensions in socio cultural impacts namely public health, job creation/employment, acceptance, implementation and adoptability as well as authorities (Table 2). Public health is referred to the effect of treatment process on nearby businesses or residents, while employment rate and public support are two main societal metrics that are used in the optimization of waste management technologies.

2.2.4. Technical aspects. Technical impacts are related to the level and ability of technology applied during the process of treatment. There are five main sub criterions in technical impacts namely adaptability to existing systems, machine/equipment, time to complete the process, local labour working experience as well as handling capacity and continuous process (materials) (see Table 2). Adaptability to existing systems is referring to the likelihood of further changes occurring, and the increasing scale of potential waste increment gives urgency to addressing technical adaptation more coherently. Machine/equipment is needed to operate the treatment facility. Finally, the time to complete the process is the duration to complete the treatment process or amount that can be processed based on the type of treatment being conducted.

2.3. Multi-criteria decision-making techniques

MCDM techniques including AHP, ELECTRE, TOPSIS, VIKOR, and PROMETHEE have been used for comparing results from many different WM studies. However, as shown in Table 2, the analytical hierarchy process (AHP) technique is found to be the most widely adopted method and used in 61% of overall reviewed studies in sustainable WM. AHP with life cycle assessment (LCA) [9, 12, 23, 27-29], AHP-Another multi-criteria methodology and LCA [30-32, 34]; the most commonly applied analytical combination for achieving reliable holistic assessments of decision-making. The reason for the use of AHP is that it is a stable system, simple to comprehend, mature and, additionally, its algorithmic form offers outcomes that could be readily conveyed to decision makers [30-31, 33-34]. AHP provides reliable performance if the investigation is engaged with diverse and conflicting objectives from concerned parties [19]. In order for the decision-maker to choose from a restricted range of choices depending on their function, the AHP protocol is classified into the ranks of the selected alternative; in the end, the Option Ranking in the AHP is revealed above the preference level. The AHP technique weighting the co efficient are ascertained depended on instinctive pair wise comparison.; for e.g. [8] study preference of food and biodegradable waste management options evaluating AD, incinerator, and composting; and [14] administer organic waste composting options: assessing windrow and in vessel composting; [16] assessed waste management alternatives: incinerator, composting, and recycling. While other methods, such as [18] using PROMETHEE to evaluate indoor composting, outdoor composting, AD, wet process and transportation to the mainland for FW management.

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Table 2. The criteria and sub-criteria descriptions based on MCDM reviewed studies.

Criteria	Sub-Criteria	Description	References																			
			[8]	[9]	[10]	[13]	[14]	[15]	[16]	[19]	[22]	[23]	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]	[34]
			AHP	AHP	AHP	AHP	AHP	MCDM	AHP	AHP/ ASPID	AHP/ TOPSIS	AHP	TOPSIS	MCDA-VIP	AHP	AHP	AHP	AHP/ PROMETHEE /	AHP/ TOPSIS	Fuzzy TOPSIS	AHP	AHP/ TOPSIS
Environmental	Resources/metal/fossil/abiotic depletion	Additional energy requirements	*								*		*	*			*		*	*	*	*
	GHG emissions (CO_2 equivalent) per ton of waste	The impact of waste treatment facilities operation on the environment affects the atmosphere, water and land.		*		*				*	*	*		*	*				*			
	Land use, requirement, and contamination	Land use refers to the purpose the land serves, for example, to setting or construction of treatment facilities	*		*	*					*				*	*		*	*			
	Odour (air pollution)	Bad odour can cause uncomfortable conditions and attract pest (ecosystem quality)	*		*		*	*			*		*									
	Water pollution caused by leachate	Leachate can harm rivers located near the waste treatment facility area	*				*	*	*						*	*		*				
Economic	Capital/ Investment costs	Investment costs comprise all costs relating to: the purchase of mechanical equipment, technological installations, construction of roads and connections to the national grid, engineering services, construction works.	*	*	*	*	*	*	*	*	*		*		*	*			*	*	*	*
	Operation costs	Costs needed during the composting process	*	*	*	*	*		*	*	*	*				*			*	*	*	*
	Revenues/ Income	Revenues can be obtained from selling the products in waste treatment: electricity, heat, compost, and recycled materials.	*		*	*	*			*	*					*					*	
	Resource recovery	When energy, a material, or a product is taken from waste and used.	*											*			*					

continued

continued

Social	Public health	Effect of treatment process on nearby businesses or residents			*			*	*			*	*						*	*	*	
	Job creation/ employment	Establishing more and better employment is crucial to improving prosperity, lowering poverty and growing community stability	*		*	*				*					*						*	
	Acceptance	The process or fact of treatment being received as adequate, valid, or suitable.	*			*				*						*					*	
	Implementation and adoptability	Installing and configuring a new solution, and training staff on how it works so they're able to use it effectively	*			*										*					*	
	Authorities	Management group responsible for SWM					*	*	*			*										
Technical	Adaptability to existing systems	To adapt the treatment technology efficiently and fast to changed circumstance	*			*										*						
	Machine/ equipment	Needed to operate the treatment facility					*									*						
	Time to complete the process	Duration to complete the process or amount that can be processed					*									*						
	Local labour working experience	The workforce with specialized know-how, training, and experience to carry out more complex tasks	*			*																
	Handling capacity and continuous process (materials)	A flow production method used to manufacture, produce, or process materials without interruption	*			*																

AHP: Analytical Hierarchy Process; MCDM: Multi Criteria Decision Making; TOPSIS: Technique for Order Preference by Similarity to Ideal Solution; PROMETHEE: Preference Ranking Organization Method for Enrichment Evaluation; ASPID: Analysis and Synthesis of Parameters Under Information Deficiency; ELECTRE III: Elimination and Choice Translating Reality; VIKOR: VIseKriterijumska Optimizacija I Kompromisno Resenje(Multicriteria Optimization and Compromise Solution); CAM: Consensus Analysis Model

3. Recommendations

The MCDM itself is a subjective process that provides results, according to experts' perceptions and mostly omits the monetary assessment. The MCDM approach alone cannot define rates of output emissions or usage of resources. The MCDM, needs inputs from other tools or methods, for example, LCA [35-36]. While none of the approaches is optimal, a combined approach can often be implemented such as the integration with environmental, financial, and public priorities [26, 32-33]. Thus, for future work, a comprehensive model that incorporates diverse factors involved in prioritizing the FW management methods through the integration tri-dimensional of LCA, life cycle costing (LCC), and MCDM with integrated expansion needs to be introduced. The degree of sustainability measured by LCA, LCC, and MCDM combined achieves a fully sustainable assessment as it covers three minimum sustainability aspects: environmental, social and economic. In fact, this hybrid system has the advantage of providing LCA and LCC objectivity. A further advantage comes from the flexibility of the MCDM and the fact that it allows qualitative and quantitative criteria to be integrated: LCA, LCC and MCDM, simultaneously, include well-designed, validated and agreed research processes, the involvement of experts or expert groups with different credentials, and the participation of public or stakeholders. This combination of methods produces excellent performance: a) To perform an overview of the FW management processes, with the robustness of the LCA in environmental terms, to examine the social implications from the perspective of the community concerned, from the viewpoint of experts (MCDM), taking into account the costs of its entire life cycle (LCC); (b) Achieve a systematic sustainability assessment, and (c) Minimize uncertainty in decision-making with a view to choosing more efficient SWM systems. Given that while there are presently many tools available for sustainable evaluation, there is a greater need to highlight complementarities between tools or even to integrate possibilities than to develop new tools [36]. Furthermore, residents' waste behaviour should be studied to enhance the avoidance of civilian FW and to include recommendations to governments and related businesses. Finally, the development of an appropriate FW sorting and collection system design together with a FW prevention programme design is imperative, taking into account the limited economic resources [37].

4. Conclusions

This review concentrated on how the MCDM approach should be used to select the right treatment technology for FW. As per this summary, the literature proposes a minimum set of indicators for each sustainability dimension in the framework evaluation of WM problems. Climate change, resource degradation and ecotoxicity as a consequence of air and water emissions from FW are at least three environmental factors that should be included. With respect to the estimation of social causes, the creation of jobs, the recipient community, public health and safety tend to be the minimum issues that need addressing. On the other hand, economic implications must be assessed at least in terms of capital spending as well as the viability of technical and financial requirements for the development of treatment facilities, energy expenses for operational and maintenance costs. Eventually, the availability of resources (land, water, etc.), the logistical specifics such as treatment capability considering process treatment duration, weight of handling, as well as local labour working experience are marginal considerations that should be included in the technical dimension. Nevertheless, the resident’s individual life preference and society collective factors all have impacts on the efficiency of food sustainability along the whole food life cycle. Therefore, creative engagement with stakeholders as decision-makers for the long-term success of FW management is crucially necessary and MCDM has much to offer regarding decision-making aid for reasonable and reliable decisions on the basis of various parameters for evaluation.

References

[1] Kummu M, de Moel H, Porkka M, Siebert S, Varis O and Ward P J 2012 Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use *J. Sci. Total Environ.* **438** 477–89

[2] Liu G 2014 Food Losses and Food Waste in China: A First Estimate 66 Retrieved Online : 17/12/2020 Available: http://www.oecd-library.org/docserver/download/5jz5sq5173lq.pdf?expires=1399902900&id=id&accname=guest&checksum=827763753514AD7F847D436DEE7F24A0
[3] Vermeulen S J, Campbell B M and Ingram J S I 2012 Climate change and food systems *J. Annu. Rev. Environ. Resour.* **37** 195–22
[4] Hall K D, Guo J, Dore M and Chow C C 2009 The progressive increase of food waste in America and its environmental impact *J. PLoS One* **4** 9–14
[5] Hartmann H and Ahring B K 2006 Strategies for the anaerobic digestion of the organic fraction of municipal solid waste: An overview *Water Sci. Technol.* **53** 7–22
[6] Bernstad A and La Cour Jansen 2012 Review of comparative LCAs of food waste management systems - Current status and potential improvements *J. Waste Manag.* **32** 2439–55
[7] Gentil E C, Gallo D and Christensen T H 2011 Environmental evaluation of municipal waste prevention *J. Waste Manag.* **31** 2371–79
[8] Babalola M A 2015 A multi-criteria decision analysis of waste treatment options for food and biodegradable waste management in Japan *J. Environments* **2** 471–88
[9] Ghazvinei P T, Mir M A, Darvishi H H and Ariffin J 2017 University Campus Solid Waste Management Combining Life Cycle Assessment and Analytical Hierarchy Process *Springer International*
[10] Abba A H, Noor Z Z, Yusuf R O, Din M F M D and Hassan M A A 2013 Assessing environmental impacts of municipal solid waste of Johor by analytical hierarchy process *J. Resour. Conserv. Recycl.* **73** 188–196
[11] Shukor J A, Omar M F, Kasim M M, Jamaludin M H and Naim M A 2018 Assessment of composting technologies for organic waste management *J.* Assessment **9** 1579-87
[12] Abba A H 2014 Doctoral Dissertation *Universiti Teknologi Malaysia*
[13] Masebinu S O, Akinlabi E T, Muzenda E, Mbohwa C, Aboyade A O and Mahlatsi T 2016 Environmental sustainability: multi-criteria decision analysis for resource recovery from organic fraction of municipal solid waste *IEEE Int. Conf. Ind. Eng. Eng. Manag.* 1543–47
[14] Zaini N S, Ezlin N, Basri A, and Zain S 2015 Selecting the best composting technology using analytical hierarchy process (AHP) *J. Tekno. Sci. & Eng.* **1** 1–8
Louis G E, Magpili L M and Pinto C A 2007 Multi-criteria decision making and composting of waste in the municipality of Bacoor in the Philippines *Int. J. Environ. Technol. Manag.* **7** 351–68
[15] Samah M A A, Manaf L A, and Zukki N I M 2010 Application of AHP model for evaluation of solid waste treatment technology *Int. J.* **1** 35–40
[16] Arıkan E, Şimşit-Kalender Z T, and Vayvay O 2017 Solid waste disposal methodology selection using multi-criteria decision making methods and an application in Turkey *J. Clean. Prod.* **142** 403–12
[17] Erceg O and Margeta J 2019 Selection of food waste management option by promethee method *Elektron. časopis građevinskog Fak. Osijek* 19 87–97
[18] Stefanović G, Milutinović B, Vučićević B, Denčić-Mihajlov K and Turanjanin V 2016 A comparison of the analytic hierarchy process and the analysis and synthesis of parameters under information deficiency method for assessing the sustainability of waste management scenarios *J. Clean. Prod.* **130** 155–65
[19] Karagiannidis A and Moussiopoulos N 1997 Application of ELECTRE III for the integrated management of municipal solid wastes in the greater Athens area *Eur. J. Oper. Res.* **97** 439–49
[20] Hung M L, Wen Ma H and Yang W F 2007 A novel sustainable decision making model for municipal solid waste management *J. Waste Manag.* **27** 209–19
[21] Pires A, Bin Chang N and Martinho G 2011 An AHP-based fuzzy interval TOPSIS assessment for sustainable expansion of the solid waste management system in Setúbal Peninsula,

Portugal *J. Resour. Conserv. Recycl.* **56** 7–21

[22] Man Contreras F, Hanaki K, Aramaki T and Connors S 2008 Application of analytical hierarchy process to analyze stakeholders preferences for municipal solid waste management plans, Boston, USA *J. Resour. Conserv. Recycl.* **52** 979–91

[23] Wilson E J, McDougall F R and Willmore J 2001 Euro-trash: Searching Europe for a more sustainable approach to waste management *J. Resour. Conserv. Recycl.* **31** 327–46

[24] Nouri J, Ali Omrani G, Arjmandi R and Kermani M 2014 Comparison of solid waste management scenarios based on life cycle analysis and multi-criteria decision making (case study: Isfahan city) *Iran. J. Sci. Technol. Trans. A Sci.* **38** 257–64

[25] Angelo A C M, Saraiva A B, Clímaco J C N, Infante C E and Valle R 2017 Life cycle assessment and Multi-criteria decision analysis: selection of a strategy for domestic food waste management in Rio de Janeiro *J. Clean. Prod.* **143** 744–56

[26] Man Brenes-Peralta L, Jiménez-Morales M F, Campos-Rodríguez R, De Menna F and Vittuari M 2020 Decision-making process in the circular economy: a case study on university food waste-to-energy actions in Latin America *J. Energies* **13** 1–25

[27] Keng Z X, Chong S, Ng C G, Ridzuan N I, Hanson S, Pan G T and Lam H L 2020 Community-scale composting for food waste: a life-cycle assessment-supported case study *J. Clean. Prod.* **261** 1-11

[28] Huang C C and Ma H W 2004 A multidimensional environmental evaluation of packaging materials *J. Sci. Total Environ.* **324** 161–72

[29] Herva M and Roca E 2013 Ranking municipal solid waste treatment alternatives based on ecological footprint and multi-criteria analysis *Ecol. Indic.* **25** 77–84

[30] Tang Y and You F 2018 Multicriteria environmental and economic analysis of municipal solid waste incineration power plant with carbon capture and separation from the life-cycle perspective *ACS Sustain. Chem. Eng.* **6** 937–56

[31] Ulukan H Z and Kop Y 2009 Multi-criteria decision making (MCDM) of solid waste collection methodsusing life cycle assessment (LCA) outputs *Inter. Conf. on Comp. Ind. Engine.* 584-89

[32] Zhou Z, Chi Y, Dong J, Tang Y and Ni M 2019 Model development of sustainability assessment from a life cycle perspective: a case study on waste management systems in China *J. Clean. Prod.* **210** 1005–14

[33] Dong J, Chi Y, Zou D, Fu C, Huang Q and Ni M 2014 Energy-environment-economy assessment of waste management systems from a life cycle perspective: model development and case study *J. Appl. Energy* **114** 400–08

[34] Myllyviita T, Holma A, Antikainen R, Lähtinen K and Leskinen P 2012 Assessing environmental impacts of biomass production chains - application of life cycle assessment (LCA) and multi-criteria decision analysis (MCDA) *J. Clean. Prod.* **29–30** 238–45

[35] Campos-Guzmán V, García-Cáscales M S, Espinosa N and Urbina A 2019 Life cycle analysis with multi-criteria decision making: a review of approaches for the sustainability evaluation of renewable energy technologies *J. Renew. Sustain. Energy Rev.* **104** 343–66

[36] Zhu S, Gao H and Duan L 2018 Latest research progress on food waste management: A comprehensive review *IOP Conf. Ser. Earth Environ. Sci.* **153** 1–8