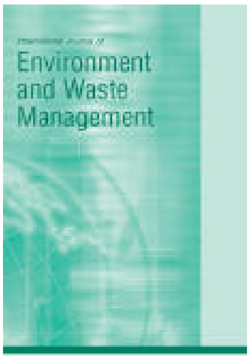

International Journal of Environment and Waste Management

ISSN online: 1478-9868 - ISSN print: 1478-9876
https://www.inderscience.com/ijewm

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DOI: 10.1504/IJEWM.2023.10051175

Article History:

Received:	11 February 2021
Accepted:	02 March 2022
Published online:	30 December 2024

Solid waste characterisation and recycling potential for a university campus in a developing nation

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Abstract: The present study aims to estimate the recyclable potential of the solid waste generated from a University Campus in India through detailed characterisation, quantification, and economic analysis. The study found high fraction of organics (36%) followed by plastic (27%) and paper (17%). The overall recycling potential was 78%. With an efficient integrated solid waste management system in place, it was estimated that the net recyclable waste of 216 tons generated from the university campus could generate revenue of 2.6 million INR (USD $36,500) annually. As a part of the waste management framework, plastic, paper, metal, and glass components were found to have immense potential of sale to local scrap dealers. Organic waste can be recycled directly on-site at the campus in the form of compost and/or biogas. The solid waste management framework proposed in this study for university campuses can be simulated for educational campuses, following circular economy (CE) approach.

Keywords: university campus; waste management; waste characterisation; recycling potential; economic valuation.

Reference to this paper should be made as follows: Jaglan, A.K., Sharma, H.B., Vinaik, M. and Dubey, B.K. (2025) 'Solid waste characterisation and recycling potential for a university campus in a developing nation', *Int. J. Environment and Waste Management*, Vol. 36, No. 1, pp.33–48.

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1 Introduction

With a growing emphasis on higher education, there is a rise in the number of universities and other residential educational campuses (RECs) across the globe. With facilities like on-campus housing, local transportation, public infrastructure, recreational facilities, restaurants, etc., nowadays universities function like small towns with transient and permanent populations from different sections and backgrounds. A campus-specific design of waste management system which incorporates all the necessary logistics of waste like quantity, nature, composition, variability, etc., can cater to the financial and environmental sustainability of the campus.

However, shortcomings of necessary infrastructure, incompetence of existing systems, inadequate knowledge of better waste management practices, and mistrust between different stakeholders involved could be responsible for serious environmental concerns at campuses, especially in developing countries like India. Hence, there is an urgent need to develop a process and framework of waste management incorporating the existing economic, environmental, and technological challenges (Dery et al., 2018). The goal of this framework would be to promote circular economic principles in designing waste management systems that would help in to maximise resource utilisation while delivering financially and environmentally competent products of value. RECs can act as testing beds for new ideas/approaches towards waste management in a region. The lessons learned can be implemented at other campuses and can also be scaled up for communities, municipalities, towns, and cities.

The key to the successful implementation of a waste management program is to understand the composition of the waste (Adeniran et al., 2017; Zen et al., 2016; Baldwin and Dripps, 2012; Zhang et al., 2020). Further, the determination of the utility of the waste components in terms of recycling and resource recovery becomes challenging due to improper estimation (Lorca et al., 2017). The economic value of waste recyclable is rarely incorporated into waste management systems during their design. Some of the elite universities in developed countries have facilities for recycling office papers and cardboard in all their buildings (Wilcox, 2014; Campus UNI, 2016), indigenous composting and recycling facilities (Recycle Mania, 2018). They are also known to organise awareness campaigns for promoting sustainable practices among their neighbourhoods (Elfithri et al., 2012), and conduct site-specific audits to capture spatial differences in the waste streams of RECs (Baldwin and Dripps, 2012; Mbuligwe, 2002; Smyth et al., 2010; Ramírez Barreto, 2008; Mason et al., 2003; Adeniran et al., 2017). RECs of developing countries like India on the other hand, despite their ever-growing student-staff population and quantum of waste, are not much involved in such activities. There is dearth of knowledge about institutional waste management as not much work is done on campus solid waste management especially from a developing country perspective. Further, there is a dearth of literature on evaluation or estimation of the market value of waste generated at the campus level. Not much is reported on the overall economic value of waste which represents a considerable loss of resources both in the form of material and energy.

The goal of this study was to illustrate the trends in the generation of waste by different student's activities within a residential campus. The chosen REC serves as a case study for a higher education institute of India to understand the typical nature, characteristics, and recycling potential of waste generated, which can also act as a basis for understanding waste generation patterns of other educational campuses in other parts of the world with similar economic backgrounds. More so, it can represent the economic potential of the waste with an efficient waste management plan in place.

The specific objectives of the study carried out across different student housing units (SHU) in the chosen Indian REC includes:

1 to understand the quantum and composition of the waste generated

2 to estimate its economic value

3 to estimate its recycling potential.

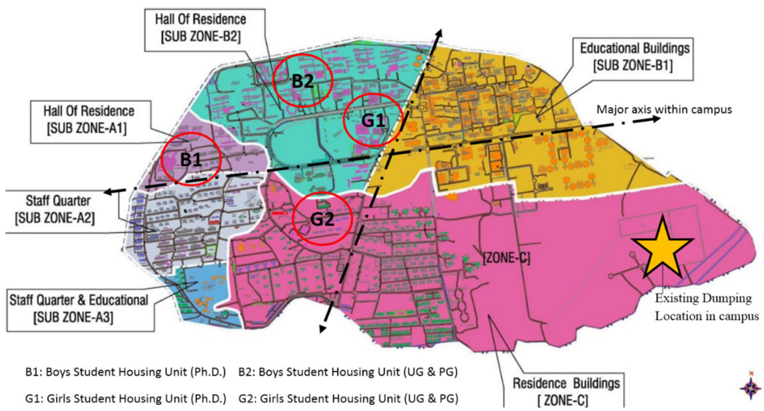
The study is expected to help understand the waste generation dynamics and its economic potential of similar educational campuses around the world and present an adaptable waste management framework for a REC which can be applied to similar communities or even can be upgraded to apply for small towns and cities.

2 Methodology

2.1 Site description

The chosen university campus (REC) is one of the oldest and largest educational campuses of India (as shown in Figure 1).

Figure 1 Map of the study site, educational campus with different zones (Colour) (see online version for colours)



The population of the campus as in July 2019 was 23,000, which includes students, faculty, staff, and their families. Academic, administrative, and community services are the main activities carried out on campus, with designated spaces for each one of them. The REC accommodates 13,000 students in 20 SHUs (13 boys and 7 girls). Data collection for the present study was done in four representative SHUs (two boys' and two girls'). These SHUs are B1 – Boys' housing PhD research scholar with a capacity of 1,390 students; B2 – boys' housing under graduate/post graduate students with a capacity of 1,680 students; G1 – girls' housing PhD research scholar with a capacity of 700 students and G2 – girls' housing under graduate/post graduate students with a capacity of 270 students. The SHUs were chosen for the data collection based on their capacity (constituting a significant fraction of campus population) to find the variability of waste with the help of detailed characterisation and to capture its typical composition.

2.2 Random sampling and characterisation of solid waste at secondary bins

Random sampling was used as the method of data collection for waste (Terashima et al., 1984). The nine categories of waste selected for the study include E-waste (power bank, electronic/LAN cable, laptop screen, bulbs, tube lights, batteries); glass (broken windows, perfumes, beverage containers, broken glassware); leather (shoes, bags, belts);

metals (tin cans, aluminium cans, wires, containers); plastics (PET bottles, HDPE); polythene (polythene bags, packaging material, i.e., soft plastic); paper (packaging cardboard, newspaper, magazines, drawing sheets, printed-papers, paper cups, notebooks); textiles (mattress, used clothes) and organics (food waste leftover, untouched food).

2.3 Quantification of daily waste generated from four selected SHUs

The estimation of daily generation was carried out based on the weight of different components collected from the primary collection points within the respective SHUs, as explained above. According to the capacity of the SHUs, in addition to the waste bins on individual stories, there were different primary waste collection points as well. The quantity of solid waste generated by each SHU within its boundary was measured and noted separately and later summed up. For doing this, waste was manually segregated into nine different categories (as listed above) from the pile of all the unsegregated waste, collected at the secondary bins of each SHU. Thereafter, the weight of the segregated waste generated under each category was measured using a digital weighing machine for each SHU. The waste generation data was collected for a period of 30 days, during June–July 2019. The data collected for 30 days was used to estimate the average waste generation rate for each of the waste categories. The average rate was used to estimate the waste generated from each SHU per month and the annual generation for the entire 20 SHUs on campus.

Since the nature of activities carried out by different REC across the world, irrespective of their location is similar, whether it is the admission process, accommodation in SHUs or organisation of cultural and academic festivals, hence the information collected for the chosen REC can be generalised. This will allow for the findings of this study to be customised and replicated in RECs world over.

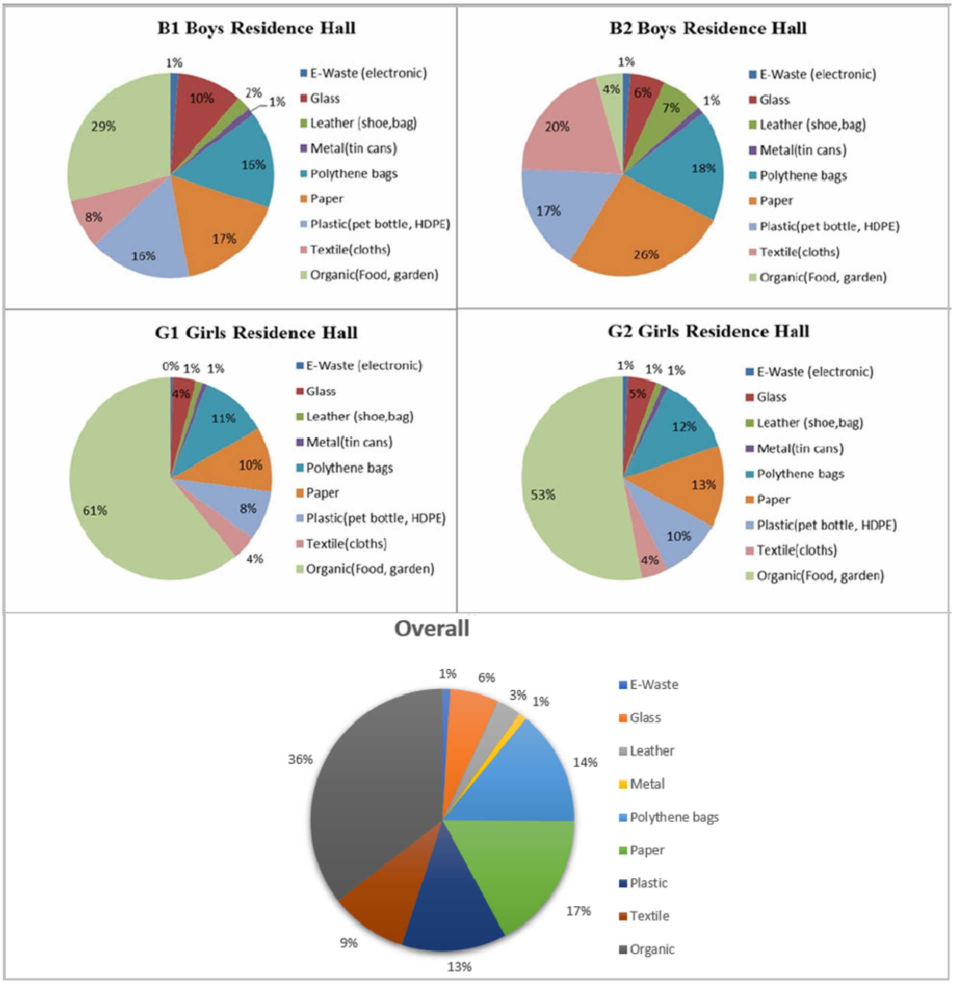
Moreover, for developing nations like India, the Solid waste management rules, 2016 mandate that all resident welfare and market associations and gated communities with an area of above 5,000 sq m will have to segregate waste at source into material like plastic, tin, glass, paper and others and hand over recyclable material either to authorised waste-pickers and recyclers or to the urban local body. Institutional generators, market associations, event organisers and hotels and restaurants have been directly made responsible for segregation and sorting the waste and manage in partnership with local bodies. In case of an event, or gathering of more than 100 persons at any licensed/unlicensed place, the organiser will have to ensure segregation of waste at source and handing over of segregated waste to waste collector or agency, as specified by the local authority. Since, RECs enact like gated communities in terms of area, the nature of activities and characteristics of waste these rules can apply to them (CPCB, 2016). Given these common characteristics, the present study is comparable with other RECs.

3 Results and discussion

3.1 Waste characterisation

In total 6,526 kg of waste was segregated from four SHUs during the 30 days Figure 2.

Figure 2 Waste compositions: overall and of the selected four SHUs on campus (see online version for colours)



The percentage composition for each category of waste for each SHU was calculated using the simple formula of:

$$C_i = \frac{X_j}{Y_i} * 100. \tag{1}$$

C = Percentage composition of each category of waste for each SHU

X_j = quantity of category of waste generated

Y_i = quantity of total waste generated by the SHU

i = B1, B2, G1 and G2 (Residence SHUs selected for the study)

j = E-waste, glass, leather, metal, polythene, paper, plastics, clothes and organic

3.1.1 Category wise waste characterisation

The waste at the SHU can be categorised into a nine main categories (E-waste, glass, leather, metal, polythene, paper, plastic, textile and organic). The quantity of organic waste was the maximum (2317.354 kg per month). The biggest contributors to the organic fraction were the food waste coming from the respective rooms of the students. Organic waste category has huge potential for compost production (Westerman and Bicudo, 2005). The paper waste accounted for around 1,109 kg which mainly comes from stationery waste of notebooks, books and printouts. The recycling of paper waste can help generate revenues Table 3.

The SHUs produce 924 kg of polythene and 842 kg of plastic per month, respectively. These are mainly constituted of packaging materials, PET bottles, disposable plastic bags, single use shampoo bottles, etc. Plastics and polythene pose threats to the environment which require immediate attention. The recycling of plastic would not only help eliminate aforementioned threats, it would also reduce the need for virgin material Table 1.

Table 1 Recycling potential for municipal solid waste components (as per review of literature)

Municipal solid waste category	*Recycling potential* [a]		
	1	*2*	*3*
E-waste		Y	
Glass	Y		
Leather			Y
Metal	Y		
Polythene	Y		
Paper	Y		
Plastics	Y		
Clothes			Y
Organic		Y	

Notes: [a]1 = Waste for which there exists a recycling market
2 = Recyclable waste for which there does not exist a local market
3 = Non –recyclable waste.

About 619 kg of textile waste are generated from the SHUs per month. These waste include rags, discarded clothes, torn bedsheets, etc. Although the proportion is low, the main issue with textile waste is its low recyclability Table 1.

This category of waste has a limited potential of being up-cycled but if collected separately (without mixing it with other waste types) this can change, as fibres from textile waste can be recycle. The broken bottles, photo frames, perfume bottles, etc., constituted about 393 kg per month. Glass waste can be sold to scrap dealer/recyclers to earn revenues due to its high recyclability Table 1 and Table 3.

The SHUs generates approximately 195 kg of leather waste per month constituting of shoe rags and torn belts. With high recycling potential and large potential to generate revenues Table 1 and Table 3, metal waste constitutes a very low proportion of total waste generated by the SHUs. The SHUs generate about 68 kg of metal waste per month.

The SHUs generate 59 kg of e-waste per month, which is the lowest proportion among total waste generated. Overall waste generated from the SHUs is shown in Figure 2.

The volume of waste generated was high during sampling period of the year because, June–July marks the period where students graduate and vacate their rooms, leaving behind heaps of cardboard, paper, plastic waste. During this period newly, admitted students also join their respective hostel that generates additional waste through new essential shopping thus creating packaging waste. This period marks the peak time during the year when waste generation is at maximum in the residential campus. More so, being a residential education campus, the rate of waste generation is influenced by the time of the year such as the admission process, the annual fests and other events which witness a surge in the generation of waste; whereas, vacations witness a slight decline (reduced activities). While comparing waste from all the four SHUs, organic waste was the largest proportion of the waste generated, of which, B1 generated about 29% organic waste, G1 generated 61% and G2 53%. The mismatch between the demand and supply of food in the mess is the major reason behind the same. Poor taste and quality of food could also be the other reasons for the large quantity of food waste among the waste generated in SHU. The food waste that was generated was mixed with all the other waste type at the primary collection points and hence reduces its resource recovery potential.

3.2 Estimation of waste generated from 20 SHUs

All the 20 SHUs of the chosen Indian REC generated an estimated 33,000 kg of waste (as shown in Table 3) during the period of the data collection (June–July 2019).

An approximation of waste quantities for the twenty SHUs was done from the data collected from the four housing units to arrive at a close representation of all the SHUs on campus. The calculations were worked out in two parts. In the first part, each of the categories of waste was first summed up to arrive at waste component wise quantities generated for the designated period for the four SHUs in total. Then, to calculate the waste wise quantities for 20 SHUs of residence, the following formula was applied for each category of waste,

$$T_i = \frac{X_i}{4} * 20 \qquad (2)$$

T Total (waste for 20 SHUs of residence) of each category of waste for each SHU of residence

X_i quantity of category of waste generated

i E-waste, glass, leather, metal, polythene, paper, plastics, clothes and organic

To estimate the approximate waste composition (in%) (waste component wise for 20 SHUs), the following formula was used,

$$P_i = \frac{X_i}{Y_i} * 100 \qquad (3)$$

P Percentage composition of each category of waste for 20 SHUs

X_i quantity of category of waste generated

Y_i quantity of total waste generated by 20 SHUs

i E-waste, glass, leather, metal, polythene, paper, plastics, clothes and organic

When discussing the share of each category of waste in total waste generation, it was observed that organic waste has maximum share (36%) and E-waste has the minimum (approximately 1%).

3.3 Campus waste recycling potential

Once quantification and characterisation were completed, then waste recycling potential of the waste generated from twenty SHUs was estimated (Ugwu et al., 2020; Zhang et al., 2020). To do the same, waste was categorised into three categories namely: Waste with an existing recycling market, Recyclable waste with no existing recycling market, and Non –Recyclable waste components respectively. Five of the waste categories (Glass, metal, polythene, paper, and plastics) falls under the first category; two of the waste categories (organic and e-waste) comes under the second category; and lastly, the other two categories of waste (leather and cloth) with no scope of recyclability as of now in the region are in the third category. To calculate the waste wise distribution among the three categories of recyclability, the following formula was used,

$$R_i = \frac{X_i}{Y} * 100 \tag{4}$$

R Recycling potential Solid Waste category wise

X_i quantity of x falling in the respective category of recycling potential

Y total quantity of recycling potential for all categories of MSW

i 1, 2 and 3

1 Waste for which there exists a recycling market

2 Recyclable waste for which there does not exist a local market

3 Non –recyclable waste

After applying solid waste recycling potential, it was found that 56% of the waste generated from twenty SHUs could be recycled and has a market for recycling, likewise, 22% of the waste generated can be recycled but there does not exist a market for such waste, and the rest 22% cannot be recycled, as shown in Table 1.

As found by the study of the SHUs, the chosen Indian REC has huge recycling potential, as shown in Table 2.

Table 2 Comparing the waste recyclable potential obtained from the present study with previously reported value in literature

Study published	*University of Baja California*	*Prince George Canada*	*University of Lagos (a)*	*University of Lagos (b)*	*University of Jordan*	*Present study 2020*
Waste categorisation	(w/w%)	(w/w%)	(w/w%)	(w/w%)	(w/w%)	(w/w%)
Recyclable	32	49.34	11	33.3	64	55.6
Potential recyclable	34	21.61	55	41.7	25	22.2
Non-recyclable	34	28.2	34	25	11	22.2

With organic waste amounting up-to 36% it could mean that the composting and setting up of bio-gas plant both would be a viable option as there is a continuous generation of input for these two avenues. Furthermore, cumulatively paper, polythene, plastic, glass, metal, and e-waste, constituted about 52% of the waste generated for which local market was available. If this system of resource recovery becomes operational, about 78% of the waste generated by the SHUs will be completely treated and would additionally generate economic value. The success of idea of resource recovery and recycling would largely depend on the success of practice of source segregation (which would assure the quality of the different waste streams). The factors that would affect the recycling potential are segregation at source, attitude/perception of staff, and students of the campus towards waste management. Comparing these results with universities across the world, it was found that this proportion is lower only to the University of Jordan (64%) (Moqbel, 2018).

4 Calculation of economic benefits from recyclables

Different countries across the world have been implementing waste recycling at varied levels, such as setting up of material recover facility, windrow composting, anaerobic digestion among others. Most studies discuss about the waste quantification and characterisation, recycling potential and developing of solid waste management plan. Few concentrates on the costing and the budgetary requirements for setting up the same (Balasubramanian, 2021). As per one of the studies, the capital cost of material recovery facility (MRF) consists of construction cost, engineering cost, and equipment cost. Construction cost was calculated by the multiplication of construction cost rate with the required floor area for MRF. Construction cost rate was taken as US$ 78 per m2 collected from an existing Municipal Solid Waste processing site in the Indian city of Mumbai (Sharma and Chandel, 2021). To develop a comprehensive waste management plan the economic and infrastructural aspects need to be taken into consideration.

Waste quantification and characterisation along with the estimation of recycling potential serve as essential factors for the assessment of economic benefits (Zhang et al., 2020). Inculcating necessary discipline in the stakeholders of RECs to categorise/source segregate garbage before handing over to the local authorities can help in achieving smooth and efficient recycling. As discussed above, the chosen Indian REC with respect to its SHUs has a huge potential for generating revenues by adopting proper waste management in terms of recyclables, with the pre-requisite of proper source segregation practices. For undertaking the economic valuation of waste, the market value of each category of waste was enquired from the local market. After gaining knowledge of the market price of each of the categories of waste, their respective economic value was estimated in two stages. Firstly, the calculation of net recycled waste components was done followed by the calculation of Total Recycled value. These were calculated as follows:

$$N_i = \frac{W_i * R_i}{100} \tag{5}$$

N Net recycled waste

W total quantity of waste generated for 20 SHUs in kilogram

R proportion of waste that can be recycled as per literature

i category of waste and

$$TR_i = X_i * P_i \quad (6)$$

TR total recycled value

i category of waste

X net recycled waste in kilogram

P Market price of a specific category of waste in Rupees

The estimates for net recycle waste and total recycle values are as shown in Table 3.

Total approximate revenue of Rs. 26 lakh/ – i.e., 36,519 USD annually was calculated. This was generated from the total net recycled waste of 216 tons from twenty SHUs. While looking at the waste wise net recycled waste, it was found that plastic waste had the maximum quantum followed by organic waste. Although textiles were generated in a lower quantum but gathered large revenues (Rs. 7,05,979), second only to organic which generated a revenue of Rs. 9,73,288. Looking at the growing rate of student population in the near future, an overall surge is expected in the near future, further adding to the total revenues. Other contributing factors to this surge includes the digital transformation leading to greater usage of technology and hence shelling out of more e-waste, dependence on e-commerce within and outside the campus, leading to generation of waste with respect to packaging materials among others. The remote location of the campus, compels the students to order online, as the chosen REC is a mini-township in its entirety, which is isolated. More so, owing to the growing velocity of waste generation, especially plastic, polyethene and e-waste, a jump in the volume of each category of waste is presumed. This revenue can be used for the betterment of the waste recycling facility on campus as well as for adopting better waste management practices within the SHU.

5 Proposed framework for sustainable solid waste management in university campus using circular economy approach

A circular economy (CE) is a regenerative alternative that aims to minimise resource input and waste output by closing material and energy flow into slow and narrow process loops (Orloff, 2017). By taking a circular approach, businesses from different industries can save up an average of 40% in material costs just recovering and reusing spent materials and products. The CE creates many opportunities in the areas of eco-design, waste revalorisation, upgrading, recycling, etc. but, even when the main purpose of this approach is closing the loop, not all the entrepreneurship possibilities are limited to the product/resource life cycle. The CE promises high quality and long-lasting jobs that improve conditions for workers in groups where short term, unstable contracts are increasing. Experts state that apart from reducing waste generation and the dependence on energy and natural resources this model could bring 70% cut in carbon emissions by 2030, contributing thus to achieve the Paris agreement goals (Orloff, 2017).

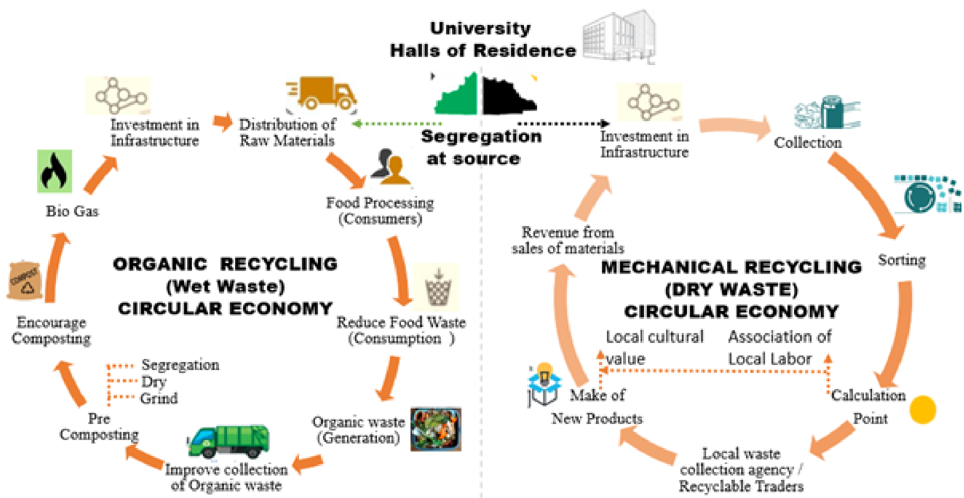
Table 3 Market value (economic value) of all category of waste from SHUs

Category	*4 SHU for one month (kg)*	*20 SHU for one month (kg)*	*20 SHU for one year (kg)*	*Percentage (20 SHU)*	*Market price (per kg)*	*Recyclable potential as reported in literature*	*Net recycled waste (kg)*	*Total recycled value (INR)*
E-waste	60	296	3,547	0.91	30	58% [a]	2,057	61,721
Glass	393	1,963	23,559	6.02	2	75% are recycled and 25% are wasted or damaged [b]	17,669	35,338
Leather	195	974	11,690	2.99	0	-	0	0
Metal	68	338	4,057	1.04	30	100% [c]	4,057	1,21,716
Polythene bags	924	4,618	55,420	14.15	3	80% [d]	44,336	1,33,008
Paper	1,110	5,547	66,561	17.00	10	27% [e]	17,971	1,79,715
Plastic	842	4,211	50,530	12.90	9	94% [f]	48,898	4,40,084
Textile	619	3,096	37,157	9.49	20	95% [g]	35,299	7,05,979
Organic	2,317	11,587	1,39,041	35.51	21	1/3 compostable waste as output [h]	46,347	9,73,288
Total	6,528	32,630	3,91,562	100.00			2,16,636	26,50,851

Notes: [a] (MRAI, 2019; Shahbaz et al., 2017; Mohanty, 2018; Shirodkar and Terkar, 2017); [b] (Mohanty, 2018, Shahbaz et al., 2017, MRAI, 2019); [c] (Shahbaz et al., 2017; Mohanty, 2018; MRAI, 2019); [d] (Mohanty, 2018; MoHUA, 2019; Shahbaz et al., 2017; MRAI, 2019) 94% waste comprises of thermoplastic content, which is recyclable such as PET, LDPE, HDPE, PVC, etc. and also other than electronic waste the plastic waste which is present in electronic waste is considered as plastic waste; [e] (Samaddar Sujeet, 2018; Rita, 2014; Judge and Patel, 2018; CPPRI, 2014, Shahbaz et al., 2017, MRAI, 2019); [f] (Mohanty, 2018; MoHUA, 2019; Shahbaz et al., 2017; MRAI, 2019); [g] (Hill, 2019); [h] (Devkota et al., 2014). (1 INR = 0.014 USD).

Given the recycling potential and the quantity of waste being generated, the REC can generate substantial revenues if efficient waste management principles are adopted. Plastic, paper, metal, and glass constitute about 51% of the waste generated and shows immense potential of revenue generation by recycling it. Paper waste would lose its value if it is mixed with other forms of wet organic waste and hence needs to be properly segregated. Plastics with their high calorific value have a great opportunity for energy recovery (Antelava et al., 2019). Interestingly it was observed that a high percentage of film plastics (polythene bag) are being used. Organic waste (36% of the waste generated) was one such category of waste which can be recycled directly on-site at the campus, to produce biogas, manure, biofuel by setting up a decentralised treatment units (Sharma et al., 2021). When implemented efficiently, this decentralised strategy would bring three-pronged benefits of environmental, socio-economic and financial (Sharma et al., 2021). The suggested framework must be implemented starting from each SHU to the entire REC following the mechanism of source segregation. The segregation should follow three categorical bin system, one each for paper, plastic and organic waste. After segregation, each category of waste should be quantified. Paper, plastic, the glass should be sorted to recyclable and non- recyclable categories Figure 3.

Figure 3 Profitable shift to circular economy concept for dry and wet waste produced from SHUs on campus (see online version for colours)



Once segregated as dry waste, this waste will be collected at a designated facility, where it will be subject to sorting based on different categories of waste and will be weighed (calculation point). The recyclables could be sold in the open market. Simultaneously, the dry waste such as cardboard and certain plastics can be upcycled to make new products. Both these activities will generate revenues that can feed into further development of infrastructure for waste management. The segregated wet waste needs to transported properly for pre-composting, where it will be subject to preparation for composting and then the process of composting. Organic waste being one of the largest proportions of waste being generated, there is huge potential for generation of biofuel (Sharma and Dubey, 2020). This can help earn revenues, which can feedback into the infrastructural development for waste management. Overall, this will create economic-environmental benefits, hence, resulting in strong waste management policies and continued sustainable development of the campus.

The resource recovery here includes recyclables from the waste stream (e.g., plastics, paper, etc.) as well as the recovery of energy from food and other organic waste. This study will help in understanding on how to develop the plan for residential campuses and the research results will be a good addition to waste management literature in this subject area. The need of this study arises because; despite of the rising quantities of waste with the rising population, the waste is not being regulated and treated properly. The value that waste can generate can be extracted if and only if waste is managed from its source. So, the present study has presented the baseline for the same by taking the case of residential educational campus.

From a policy perspective, numerous guidelines, such as the solid waste management rules 2016 in India (CPCB, 2016), have been issued at state/city level but their level of implementation is low. A straight-jacketed approach cannot be implemented, since one size does not fit all. There is need to use bottom-top approach rather than the other way round, which is being targeted by the present study. The bottom-top approach implies that the implementation of appropriate waste management framework needs to begin from the grassroots level, such as the case of residential educational campus as assumed by the present study. As discussed in the present study the implementation of the framework needs to begin with quantification and characterisation of waste, followed by the valuation of waste segregated at source. Once success is achieved at this level, the framework can be upscale to be implemented in different urban spaces of similar setting, gated communities and residential campuses.

6 Conclusions

The studied university campus has 78% recycling potential of total solid waste generated. The study revealed that the major recyclable components that have significant presence are cardboard, plastic, paper, food waste, and polythene. With an efficient integrated solid waste management system in place, it was estimated that the net recyclable waste of 216 tons generated from the university campus could generate revenue of 2.6 million INR (USD $36,500) annually. It is highly recommended to bring into action recycling programs, awareness programs to manage the waste generated from twenty student hostels. Source segregation is crucial and is the premise on which efficient implementation of the waste management system needs to be based on resource recovery and recycling. Effective framework encompassing the principles of CE can create economic value for the waste while promoting campus sustainability.

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