EVALUATING THE CAPACITY OF A BUILDING'S WASTE AND THE POTENTIAL FOR SAVINGS USING THE LIFE CYCLE ASSESSMENT METHODOLOGY

HATİCE SÖZER & HÜSEYİN SÖZEN
Energy Institute, Istanbul Technical University, Turkey

ABSTRACT

Waste and their management policies have significant effects on the environment. Hence, decision-makers have to be very careful while making decisions about waste management systems. In this research paper, a big scale building's waste was identified based on its life cycle assessment (LCA). A methodology was developed to determine the optimum saving potential from the waste management regarding the gate-to-grave system boundaries that covers two stages in the lifetime of the building: the building in use and once demolished. The case study building is an elderly house that is located in the Kartal district of Istanbul. The total conditioned floor area in the building is 18.108 m^2, the building has eight stories which accommodates 556 people including workers. The building's waste in this research was categorized as solid and liquid waste. Also, the operational energy consumption was examined with LCA methodology to compare with defined waste management system. The waste was examined in terms of EN 15978 standard which also includes the investigation of the waste transport to wasteland, waste processing and disposal stages. The Turkish Statistical Institute (TUIK) was used as a reference to obtain the waste production per capita. The LCA results showed that there is an energy recovery potential from generated waste of the case study building. Especially, municipal solid waste (MSW) have significant energy recovery potential because of the recycling processes. Cumulative energy demand (CED) of all waste management systems is -107.956 kWh/year. Nonetheless, the potential compensate only 1.5% of total CED of operational energy consumption. If the recyclable waste could handle a proposed management system, the compensation rate could be increased and a more significant rate could be achieved. On the other hand, global warming potential (GWP) of the whole waste management system is 117.682 kg CO_2eq./year which is 14 times smaller than GWP of operational energy.

Keywords: life cycle assessment, waste management, municipal solid waste, liquid waste, demolition waste.

1 INTRODUCTION

Turkey's population is approximately 80 million, and Istanbul population is over than 15 million [1]. The growing population causes a serious waste management problem that has to be managed in multidisciplinary perspective. The amounts of waste are increasing due to population and consumer behavior. There are many parameters that have to be taken into account to determine a waste management system for municipal scale or building scale; furthermore, life cycle assessment (LCA) methodology could be used to define a management system by authorities. Sharma et al. [2] gives a definition for LCA. According to them, LCA is a tool to make quantitative calculation on material, energy flows and their environmental impacts; besides, it includes obtaining raw material, manufacturing, use and final disposal steps. The methodology of LCA has different system boundaries, and "cradle-to-grave" is the most detailed one. One of the other system boundaries is "gate-to-grave" where production phase is not included in the system. It only includes building in use and end of life stages. Di Maria and Micale [3] modified their system boundaries as gate-to-grave in their paper related with waste management in Italy. Thus, wastes were investigated during

WIT Transactions on Ecology and the Environment, Vol 231,
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/WM180151

generation and disposal phases that includes demolition, transportation, waste processing and landfill steps.

The main methodology for LCA is defined in ISO 14040 standard. The standard defines 4 main steps as: goal and scope definition, inventory analysis, life cycle impact assessment and interpretation [4]. In addition to that, there is also a European norm for LCA that is called EN 15978 where it is defined the Sustainability of construction works under the Assessment of environmental performance of buildings with a calculation method. EN 15978 is used to examine environmental performance of building in 5 stage as: Product (A1-A3), construction process (A4, A5), use (B), end of life (C) and benefits and loads beyond the system boundaries (D) stage [5]. Only, B and C stages were examined based on defined system boundaries in "*Goal and Scope*" section. Use (B) stage includes only operational life time of the building such as operational energy, water usage etc.; besides, end of life (C) stage includes transportation of waste, processes for waste handling.

The aim of this study is investigating waste capacity and waste management system of a case study building. The selected building type represents many other buildings in Turkey; hence, the results would be used as examples for similar buildings. The building's wastes in this research were categorized as solid and liquid wastes. Banar et al. [6] used to LCA methodology to determine optimum solid waste management system in terms of environmental perspective for Eskişehir/Turkey. They evaluated five different scenarios that one of them is current management strategies in Eskişehir. The Municipality made 7.5% recycling and 92.5% landfilling on the wastes in current management system; nevertheless, the results showed that scenario 3 (15% recycling, 77% composting and 8% landfilling) which was the most environmentally friendly scenario. Özeler et al. [7] investigated the best waste management system option for Ankara. Their suggested scenario in terms of environmental concerns included source reduction, collection, transport and landfilling. Erses Yay [8] worked on same purpose as the other two papers for Sakarya via LCA methodology. She has selected the scenario that included material recovery facility (MRF), composting, incineration and landfilling as the best scenario based on its environmental effect. She also offered a second option by eliminating the incineration process from the proposed scenario because of its high cost. Creating a waste management system for solid wastes is also related with solid waste characterization. Fraction of solid waste can change from city to city even so from person to person. Özcan et al. [9] evaluated municipal solid waste characterization in Kartal District. The results showed that organic waste type has the highest percentage (57.69%), and the others lined up from the highest to the lowest as plastic (8.41%), combustibles (8.01%), glass (6.13%) and the others (19.76%). Yıldız et al. [10] also worked on characterization of municipal solid waste in İstanbul. Their results showed that organic waste has the highest percentage with 53.73%, the second is paper/cardboard with 16.75%, the third one is plastic with 12.88%, and the others is 16.67%. Statistical report of TUİK analyzed and reported the municipal solid waste generation per capita per day. Istanbul rate is always higher than Turkey average. Because Istanbul is the most crowded and urbanized city in Turkey, people who live in Istanbul tend to consume more than people who live in other cities. Municipal solid waste (MSW) generation rate in İstanbul is 1.3 kg/cap./day in 2016 [1].

The other waste type that comes from buildings is liquid waste. One of those with high impact on environment is domestic wastewater. Fraction of domestic wastewater includes biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrogen types, phosphorus, suspended solids etc. as pollutants [11]–[13]. The number of wastewater treatment plants is increasing year by year in İstanbul and Turkey. According to database of Istanbul Water and Sewerage Administration (İSKİ), there are 81 wastewater treatment plants inside of İstanbul Municipality's borders [14]. In addition to wastewater, rainwater has also high saving capacity. Rainwater collection systems have been used for household or irrigation purpose for centuries [15]. Using rainwater as domestic water without treatment can be dangerous for human health because of pollutants and pathogens. Simmons et al. [16] investigated on 125 domestic rooftop rainwater systems, and their samples included *Salmonella*, *Aeromonas* and *Cryptosporidium* that are pathogens for people. On the other hand, there are various researches were reported that if the harvesting system designed properly, rainwater can be used for garden irrigation, toilet flushing, clothes washing, even so for drinking and cooking [17], [18]. Municipal wastewater generation rate in İstanbul is 226 L/cap./day in 2016 [1].

The municipal solid and liquid wastes are generated during building service life by habitants, while demolition wastes are generated during the building retrofitting or after the building life-time. As seen from published papers, fraction of demolition wastes showed differences based on purpose of building use, size of building, and main material of building. An overview on demolition waste in the UK shows that concrete percentage is 59.28% on demolition waste from buildings, after the concrete, inert materials is 20.98% and metals is 9.98% [19]. Andrea [20] analyzed residential demolition waste in Turin/Italy; also, the results showed that concrete has the highest percentage with 82.5%. Ding and Xiao [21] worked on residential and non-residential demolition waste in China, and they categorized the buildings in 3 group based on construction date as before 1980, 1980–1999 and after 2000; thus, they also analyzed changing of fraction during time. Brière et al. [22] showed the fraction as: masonry (52.8%), reinforced concrete (26.4%), mixed inert waste (9.3%) and the other (11.5%).

2 THE CASE STUDY BUILDING

The case study building is an existing elderly house that is located in Kartal district of Istanbul. The case building is located at the east part of the district that is called "*Hürriyet*" region.

2.1 The case study building description

The building was designed as an elderly house, and it has 8 story with 18,108 m^2 conditioned floor area. Approximately 556 people live in the building. The building is owned by Kartal Municipality. The material of building envelope is concrete-brick; besides, the building was retrofitted based on a European Union project scope is called R2Cities [23]. The building started its service life in March 2018 after a major retrofitting. The retrofitted activities included building envelope, HVAC, mechanical and electrical systems which covers entire building renovation between 2013–2018. Thus, building lifetime was extended approximately 50 years after 2018.

The building was designed to accommodate elderly people. Capacity of the building is 456 residences; as well, there are 100 employees for cleaning, administration, security etc. Thus, the total capacity of the building is 556 people. There are different wastes types from organic to electronic. Also, detail 3D model and energy simulation models were developed to obtain the building's proportions in detail and energy performance.

2.2 Current waste management in the case study building

Generated solid wastes are collected in garbage containers during the day; besides, Kartal Municipality is responsible to collect them from the building via garbage trucks at the end of day. Collected solid wastes in garbage trucks are sent to the closest transfer station. In Anatolian site of Istanbul, there are four different transfer stations. The selected one is Aydınlı Solid Waste Transfer Station due to closeness. It is approximately 18 km away from the case study building. Volume of solid wastes are decreased in transfer station by pressure machines. Therefore, the amount of fuel that is needed to transfer to main landfill area decreases. After transfer station, solid wastes are moved to main landfill area by larger volume trucks. There are two main landfill areas, one of them is in European side and the other is in Anatolian side in Istanbul. The closet one is in Anatolian side that it is called Kömürcüoda Landfill Area, which is managed by İstanbul Metropolitan Municipality Environmental Protection and Waste Materials Valuation Industry and Trade Co. (ISTAC JS Co.). The distance between Aydınlı Transfer Station and Kömürcüoda Landfill area is approximately 49 km. Kömürcüoda landfill has compost and recycling facilities. It means that the plant offers recycling, composting and landfilling options for solid wastes. Mechanical processes are applied to divide the wastes into two different categories for composting and recycling. Recycling materials are divided in terms of their raw material such as glass, metal. Compost products that are suitable for refuse derived fuel (RDF) are used in cement industry as fuel. The residual wastes are buried into a landfill area. Leachate is collected with pile line to treatment; besides, biogas comes from wastes is collected to generate electricity. According to Istanbul Municipality database, 84% of municipal wastes are send to landfill area, 6% of them are recycled, and 10% of them are used for composting or bio-drying [24].

Wastewater that comes from parts of the building is collected by a plumbing system. Collected wastewater is generated from wet spaces such as bathrooms, toilets, kitchens and moved to urban sewerage system. Afterwards, wastewater management is responsibility of the municipality and Istanbul Water and Sewerage Administration (İSKİ). İSKİ has many wastewater treatment plants in Istanbul, Kartal district sewerage system connects to the Tuzla Advanced Biological Wastewater Treatment Plant. In addition to wastewater system, there is not rainwater collecting system in the building.

3 METHODOLOGY

ISO 14040 [4] divides LCA methodology into 4 main steps. These are listed as: *Goal and Scope Definition, Inventory Analysis*, *Life Cycle Impact Assessment and Interpretation* whereas define the paper methodology. Each step was described according to the case study.

3.1 Goal and scope definition

The purpose of the paper is analyzing environmental effects of wastes that are generated in the case study building besides cumulative energy demand of the wastes handling processes. In addition, current waste management system of the building was analyzed via the developed LCA model, and effects of end of life and operational energy consumption on the environment during building life were compared to understand their relation between each other. Thus, the question if the energy recovery from waste process can compensate the operation energy to reach the zero energy building was answered. Despite LCA methodology can be defined as cradle-to-grave system boundaries, system boundaries were defined based on gate-to-grave system boundaries in the paper. Thus, production of the materials that are turned to wastes was not included in the model. Only generated wastes and their end of life processes were investigated. System boundaries also can be defined based on EN 15978 [5]. EN 15978 divides the building life time into five main steps. These are mentioned in the

Introduction section. According to the EN 15978, only use (B) stage and end of life (C) stage were analyzed.

Life time of model was defined as one year. However, generation of demolition wastes involves a 50 years' time period, which is the building life time. Because of that, demolition wastes were analyzed for 50 years, and their results were optimized on one year scale. Hence, results of defined indicators were also given in one year scale in the paper. The models were developed in 5 steps. (1) Waste capacity of all waste type was defined. (2) Operational energy demand of the building was obtained from energy simulation model. (3) Current waste management systems were defined based on data of municipality, ISKI and ISTAÇ (5). All processes were entered to the models carefully. Defined processes are given in Fig. 1 in detail. According to defined processes, 6% of MSW is recycled, 10% of MSW is composted and 84% of MSW is buried in landfill area. Wastewater is directly collected with sewage grid and treated in the plant. 26% of demolition waste is recycled and 74% of it is buried to landfill area. Also, system boundaries of the study are given in Fig. 2. The results of LCA were evaluated based on the one year period of building in usage.

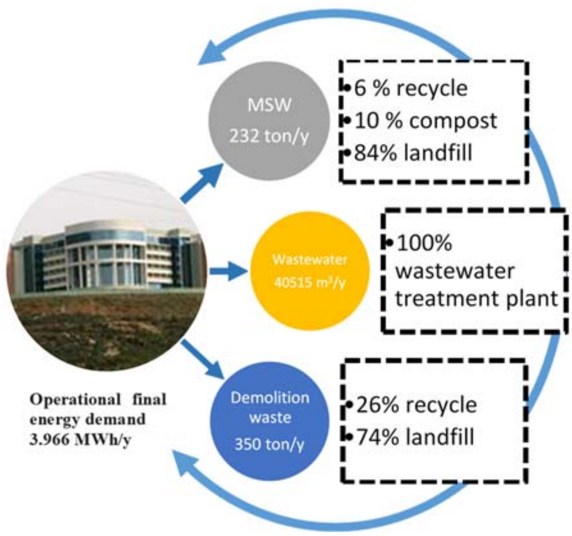

Figure 1: Defined processes for the all waste types during the one year of process.

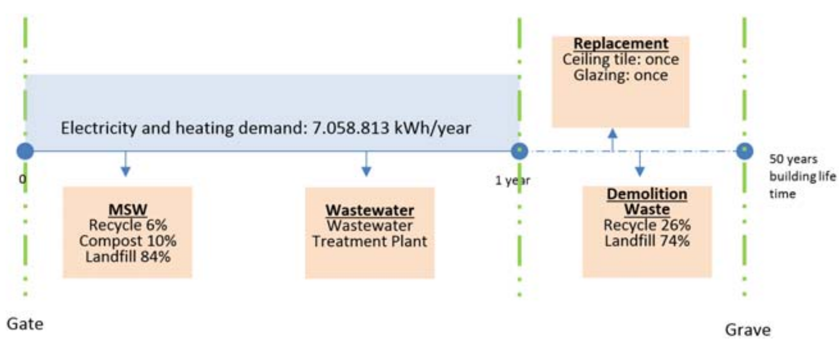

Figure 2: System boundaries based on gate-to-grave approach.

3.2 Life cycle inventory

LCA inventory includes all input and output data. For this reason, this step has highly critical effects on the results of the model. Generated wastes were used as inputs to the models; hereafter, their amounts were calculated in detail. MSW generation rate was 1,3 kg/cap/day according to TUIK database [1]. The amount of annual municipal solid wastes was calculated accordingly. The total inhabitants in the buildings are 556 elderly people who lives in the building 24 hours and 100 employee working in the buildings as administrators, nurses, cleaners, cookers. The total amount of solid waste was calculated by eqn (1). Staffs contribution was divided to 3 because their shift is every 8 hours per day.

$$\frac{The\ total\ amount\ of\ MSW}{Day} = 456x1{,}3 + \frac{1{,}3}{3}x100 = 636\ {}^{kg}/_{day} \Rightarrow 232{,}2\ {}^{ton}/_{year}. \quad (1)$$

Waste management approach does not only include the total amount of wastes; also, the fractions of solid wastes are important to define the recycling, composting, landfill processes. Literature was used to find the amount of fraction of municipal solid wastes. Özcan et al. [9] analyzed fractions of MSW in Kartal District, where the case study building is located. The fractions of MSW from the case study building are shown in Table 1. In LCA model, sub-categories of MSW were classified into 6 groups, as organic (organic and garden waste), paper (paper, cardboard and bulky cardboard), plastic, glass, metal (metal and electrical and electronical equipment) and others (hazardous wastes, other non-combustibles, other combustibles, other bulky combustibles and ash).

In addition to the MSW, generated wastewater from the case study building was included in the LCA model. Total amount of MSW, TUIK data was used for calculating the total amount of wastewater. The wastewater generation rate for Istanbul is 226 L/cap/day; thus, the calculation was seen in eqn (2). The staffs work 8 hours per day was also used in the calculation.

$$\frac{The\ total\ amount\ of\ Wastewater}{Day} = 456x226 + \frac{226}{3}x100 = 110589\ {}^{L}/_{day} \Rightarrow 111\ {}^{m^3}/_{day}. \quad (2)$$

Demolition wastes are also another waste type that was analyzed based on defined system boundaries. Building Information Modelling (BIM) was used to calculate the building demolition wastes capacity. Fractions of demolition waste and the total amount of demolition waste can be seen in Table 2.

Table 1: Fraction of the case study building based on building solid waste [9].

Building solid waste fraction	Fraction (%)	Amount of tons/year
Organics	60.62	141
Paper and cardboard	10.98	25
Plastic	8.41	20
Glass	6.13	14
Metal	1.01	2
Electrical and electronical equipment	1.23	3
Others	11.62	27
TOTAL	100	232

Table 2: Fractions of demolition wastes.

Material	Mass (tons)	Fraction (%)	Material	Mass (tons)	Fraction (%)
Brick-common	5,471	31.33	Plaster	103	0.59
Ceiling tile	13	0.08	XPS	37	0.21
Concrete	11,117	63.66	Wood	48	0.28
Glass	204	1.17	Plastic	5	0.03
Marble	11	0.06	Others	453	2.59

In addition, operational energy consumption was also analyzed to compare with produced wastes. Also, results were included in energy performance analysis to reduce the overall energy consumption of the building to achieve the nearly zero energy concept with defined waste management systems. A model that was created in Design Builder (v5.3.0.008) software and simulated to calculate energy consumption of the building [25]. Energy consumption results were obtained into two group: Heating (138 kWh/m^2.year) and electricity (81 kWh/m^2.year) as final energy consumption.

3.3 Defined environmental indicators

Two indicators were defined in the paper. These are global warning potential (GWP) and cumulative energy demand (CED).

- GWP: It represents greenhouse gases emission that comes from processes to the environment. The most important gases that cause greenhouse effect are methane (CH_4) and carbon dioxide (CO_2). However, unit of GWP was defined as kg CO_2 equivalent. It means that other greenhouse gases except CO_2 effects on the environment were converted into CO_2eq. in results. Also, GWP was calculated by IPCC 2013 GWP 100a method.
- CED: It includes primary and cumulative energy consumption instead of end-user's consumption. Because of that, it is more suitable for zero energy approach and the environmental effects. Unit of CED was defined as kWh in the paper. Besides, cumulative energy demand method was used to calculate CED.

4 RESULT

The LCA model was developed based on defined system boundaries and inventory database; also, the results were obtained based on defined indicators. LCA model was run in SimaPro 8.5.0.0; hence, Ecoinvent database was used on the calculation [26]. MSW and wastewater models was run for one-year time period. On the other hand, generation time of demolition wastes is more than one-year, and it is mostly related with life time of buildings. The case study building life time was defined as 50 years because it was renovated in 2018. Thus, demolition wastes model was run for 50 years. After that, its results were given as per year to compare with MSW and wastewater management model.

CED results of the waste management model based on processes are represented in Table 3. Processes were divided into different groups as: transportation, recycle, sanitary landfill, compost and wastewater treatment. While MSW model was included all processes (recycle, sanitary landfill and compost), certain processes in specific wastes were not applicable such as compost processes were not suitable for the glass wastes as demonstrated on Tables 3 and 4. With this division, impact of processes on CED was examined individually. As it seen, only recycling process has energy recovery potential while the other processes consume

Table 3: CED results of the waste types based on processes.

Waste type	Transportation (kWh/year)	Recycle (kWh/year)		Sanitary landfill (kWh/year)		Compost (kWh/year)		Wastewater treatment (kWh/year)	CED (kWh/year)
MSW and wastewater	25,056	-180,279	6%	21,361	84%	2,264	10%	2,381	-129,329
Glass	1,536	-15,833	21.5%	1,217	78.5%	–		–	-13,082
Metal	564	-5,000	21.5%	444	78.6%	–		–	-3,994
Paper	2,753	-76,945	21.5%	2,181	78.7%	–		–	-71,970
Plastic	2,108	-81,667	21.5%	1,678	78.8%	–		–	-77,963
Organic	15,222	–		12,861	83%	2,264	17%	–	30,337
Others	2,914	–		2,944	100%	–		–	5,870
Electricity and heating	–	–		–		–		–	7,058,813
Wastewater treatment	–	Municipal wastewater treatment						2,381	1,473
Demolition wastes	7,278	-15,000	24%	2,9056	76%	–		–	21,372

Table 4: GWP results of the waste types based on processes.

Waste type	Transportation (kg CO_2eq./year)	Recycle (kg CO_2eq./year)		Sanitary landfill (kg CO_2eq./year)		Compost (kg CO_2eq./year)		Wastewater treatment (kg CO_2eq./year)	CGWP (kg CO_2eq./year)
MSW and wastewater	6,050	-16,800	6%	122,000	84%	4,830	10%	663	117,068
Glass	376	-3,980	21.5%	7,000	78.5%	–		–	3,396
Metal	138	-1,910	21.5%	2,560	78.6%	–		–	787
Paper	665	-2,585	21.5%	12,500	78.7%	–		–	9,965
Plastic	515	-7,690	21.5%	9,610	78.8%	–		–	2,441
Organic	3,720	–		73,700	83%	4,830	17%	–	82,236
Others	713	–		16,900	100%	–		–	17,629
Electricity and heating	–	–		–		–		–	1,671,454
Wastewater treatment	–	Municipal wastewater treatment						663	633
Demolition wastes			24%	29,056	76%	–		–	117,856

energy. Also, transportation of wastes consumes energy because of fuel demand. Compost, sanitary landfill and wastewater treatment similarly consume energy due to their sub-processes.

CED results in each process were given in Table 3 in detail. Total amount of wastes based on weight was calculated as an input to the model. Likewise, waste management models are seen under process column. Recycling, composting and sanitary landfill percentage were defined in detail. Results of waste management models as well as result of sub-categories are calculated and represented in Table 3. Model of MSW and wastewater showed that their current management systems recover 129,329 kWh/year energy. On the other side, demolition waste management system causes 21,372 kWh/year consumption. Overall result demonstrated that MSW, wastewater and demolition wastes management systems can recover 107,957 kWh/year. If the building conditioned area was considered, 2.25 kWh/m^2.year can be recovered with the current waste management system. As seen in Table 4, the most effected sub-groups are plastic and paper wastes on energy recovery rate because their fraction are higher than others on MSW. Paper fraction is 10,98%, and plastic fraction is 8.41% while metal's only is 2.24%. GWP results differ than CED as can be seen in Table 4. Results of MSW and wastewater model show that their management system releases 117,068 kg CO_2eq./year; also demolition waste management system cause 117,856 kg CO_2eq./year emission. Thus, overall result display that MSW, wastewater and demolition wastes management systems cause 234,924 kgCO_2eq./year greenhouse gases emissions. If the building conditioned area was considered such as in CED results, 4.9 kg CO_2eq./m^2.year greenhouse gases emissions come from waste management systems of the case study building as represented in the Table 4. The most effected waste sub-group in GWP is organic and demolition wastes due to their buried processes into sanitary landfill areas.

Results of MSW, wastewater and demolition waste types were given in Tables 3 and 4. CED and GWP results show that the current management system of MSW has positive effect on the environment based on CED and negative effect on the environment based on GWP. Besides of that, wastewater treatment and demolition waste management systems have negative effect on the environment based on both indicators. Also, the building uses operational energy for heating and cooling and electricity. The operational energy also were examined with LCA methodology to compare with waste management systems. However, CED of operational energy is surely higher than the CED of waste management systems as expected. Its operational energy is 219 kWh/m^2.year. While CED of operational energy is 7,058,813 kWh/year. Total CED of all wastes (MSW, wastewater and demolition waste) is -107,957 kWh/year. Comparison between all waste types and operation energy are given in Tables 4 and 5.

Sub-categories impact also can be seen in Tables 3 and 4. Paper and plastic have significant energy recovery potential because of their amount. Also, organic wastes processes consume major energy because they are composted or buried in landfill. As it seen, results of MSW was given at first line in Tables 3 and 4. Also, sub-categories of MSW such as glass, paper, organic etc. could be seen in same tables. Thus, results show both total effect of MSW and individual effects of sub-waste categories. Total CED of MSW is negative. Recovered energy from recycling processes is the reason for that. On the other hand, GWP of MSW is positive. Recycling processes show negative effect on there, but fuel demand of transportation and landfill processes cause positive results. GWP of MSW and demolition wastes are higher than wastewater effects as it seen Table 4. Based on MSW sub-categories, GWP of organic wastes are more than other sub-categories. When it looked in general, GWP of all waste management systems are 14 times smaller than GWP of operational energy as it seen Table 4.

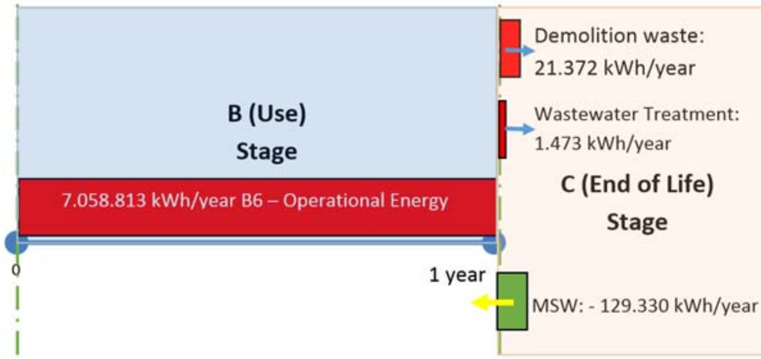

Figure 3: CED results of all inputs during one year.

Waste management system was set to control impact of wastes on environment. The results of all inputs were given in Fig. 3. The red color means energy consumption; besides, the green color means energy recovery. Also, energy recovery potential from MSW could be taken as advantage in operational energy consumption. This compensation is represented with "*yellow arrow*"; also, consumption during end of life stage is represented with "*blue arrow*" in Fig. 3.

5 CONCLUSIONS

The generated wastes at the case study building were analyzed with LCA methodology. The system boundaries were defined as gate-to-grave. Consequently, production and transportation stage of the materials that turned into wastes were not included in the models. The wastes were divided into three groups as MSW, wastewater and demolition wastes; additionally they were analyzed in different approaches. Waste management policies were defined as current management system at the buildings. After that, all of results were combined. The LCA results showed that there is an energy recovery potential from generated wastes at the case study building. Especially, MSW have significant energy recovery potential because of recycling processes.

Energy recovery potential from the wastes is comparatively low when compared with operational energy consumption. The total recycling rate in MSW is 6%. If this rate increases, recovery potential will be increased directly. Because of that, the recycling potential have to be increased with new waste management policy. As it was identified in detail, the capacity and fraction of the wastes determine the waste management methodology. The case building that is being analyzed in this research represents many other buildings within the municipal borders. The results would be very valuable as a data to analyze the rest of the municipality waste capacity and its energy saving potential. As a result, the municipality would take advantage of these results and create their own waste management strategy for entire district.

REFERENCES

[1] Turkish Statistical Institute (TUIK) Database. www.tuik.gov.tr/PreTabloArama.do?metod=search&araType=vt.

[2] Sharma, A., Saxena, A., Sethi, M. & Shree, V., Life cycle assessment of buildings: A review. *Renewable and Sustainable Energy Reviews*, **15**(1), pp. 871–875, 2011. DOI: 10.1016/j.rser.2010.09.008.

[3] Di Maria, F. & Micale, C., A holistic life cycle analysis of waste management scenarios at increasing source segregation intensity: The case of an Italian urban area. *Waste Management*, **34**(11), pp. 2382–2392, 2014. DOI: 10.1016/j.wasman.2014.06.007.
[4] ISO 14040, *Environmental Management: Life Cycle Assessment. Principles and Guidelines*, International Organization for Standardization: Geneva, 2006.
[5] EN 15978, Sustainability of construction works: Assessment of environmental performance of buildings, Calculation method, 2011.
[6] Banar, M., Cokaygil, Z. & Ozkan, A., Life cycle assessment of solid waste management options for Eskisehir, Turkey. *Waste Management*, **29**(1), pp. 54–62, 2009. DOI: 10.1016/j.wasman.2007.12.006.
[7] Özeler, D., Yetiş, U. & Demirer, G.N., Life cycle assessment of municipal solid waste management methods: Ankara case study. *Environment International*, **32**(3), pp. 405–411, 2006. DOI: 10.1016/j.envint.2005.10.002.
[8] Erses Yay, A.S., Application of life cycle assessment (LCA) for municipal solid waste management: A case study of Sakarya. *Journal of Cleaner Production*, **94**, pp. 284–293, 2015.
[9] Özcan, H.K., Guvenc, S.Y., Guvenc, L. & Demir, G., Municipal solid waste characterization according to different income levels: A case study. *Sustainability*, **8**(10), p. 1044, 2016. DOI: 10.3390/su8101044.
[10] Yıldız, Ş. et al., Characterization of municipal solid waste in Istanbul, Turkey. *Environmental Progress and Sustainable Energy,* **32**(3), pp. 734–739, 2014. DOI: 10.1002/ep.11640.
[11] Orhon, D., Ateş, E., Sözen, S. & Çokgör, E.U., Characterization and COD fractionation of domestic wastewaters. *Environmental Pollution*, **95**(2), pp. 191–204, 1997. DOI: 10.1016/s0269-7491(96)00111-x.
[12] Aziz, S.Q. & Ali, S.M., Characterization of municipal and dairy wastewaters with 30 quality parameters and potential wastewater treatment by biological trickling filters. *International Journal of Green Energy*, **14**(13), pp. 1156–1162, 2017. DOI: 10.1080/15435075.2017.1370594.
[13] Sari, S. et al., Seasonal variation of diclofenac concentration and its relation with wastewater characteristics at two municipal wastewater treatment plants in Turkey. *Journal of Hazardous Materials,* **272**, pp. 155–164, 2014. DOI: 10.1016/j.jhazmat.2014.03.015
[14] İstanbul Water and Sewerage Administration Database. www.iski.istanbul/web/tr-TR/kurumsal/iski-hakkinda1/aritma-tesisleri6/atiksu-aritma-tesisleri2.
[15] Pandey, D.N., Gupta, A.K. & Anderson, D.M., Rainwater harvesting as an adaptation to climate change. *Current Science*, **85**(1), pp. 46–59, 2003.
[16] Simmons, G., Hope, V., Lewis, G., Whitmore, J. & Gao, W., Contamination of potable roof-collected rainwater in Auckland, New Zealand. *Water Research*, **35**(6), pp. 1518–1524, 2001. DOI: 10.1016/s0043-1354(00)00420-6.
[17] Heyworth, J.S., Glonek, G., Maynard, E.J., Baghurst, P.A. & Finlay-Jones, J., Consumption of untreated tank rainwater and gastroenteritis among young children in South Australia. *International Journal of Epidemiology*, **35**(4), pp. 1051–1058, 2006. DOI: 10.1093/ije/dyl105.
[18] Hollander, R. et al., Microbiological and hygienic aspects of the use of rainwater as process water for toilet flushing, garden irrigation and laundering. *Gesundheitswesen*, **58**(5), pp. 288–293, 1996.

[19] Zakar, S., Overview of demolition waste in the UK, Construction resources and waste platform, 2009.
[20] Andrea, G., Life cycle of buildings, demolition and recycling potential : A case study in Turin, Italy. *Building and Environment,* **44**(2), pp. 319–330, 2009. DOI: 10.1016/j.buildenv.2008.03.007.
[21] Ding, T. & Xiao, J., Estimation of building-related construction and demolition waste in Shanghai. *Waste Management,* **34**(11), pp. 2327–2334, 2014. DOI: 10.1016/j.wasman.2014.07.029.
[22] Brière, R., Feraille, A., Tardivel, Y. & Baverel, O., Environmental approach of the end-of-life of buildings. *AvniR Conference*, Lille, France, Nov. 2014.
[23] 7th Framework EU Project, Residential renovation towards nearly zero energy cities (R2Cities), Project no: 314473, 2013–2018.
[24] İstanbul Municipality Database. www.ibb.istanbul/.
[25] DesignBuilder Software Ltd., DesignBuilder (v5.3.0.008). www.designbuilder.co.uk/.
[26] Pre Sustainability, SimaPro 8.5.0.0. https://simapro.com/.