Potential commercial waste in Jakarta as a renewable source of energy

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Abstract. The high development of the commercial area in Jakarta starting in the 90s which shopping centers sprawling across the city with the concept of a modern market or mall. These commercial wastes generated a high amount of wastes which contains a very high mass fraction of combustibles (such as plastic, paper, and textile). Waste that characterized by a high calorific value would suitable for direct combustion in waste-to-energy (WtE) plants. The objective of this study is to apply the waste to energy concept for utilizing commercial waste as the potential energy of Jakarta’s. The result showed that the energy content of Jakarta’s commercial waste 189.78 ± 23.51 GWh/month, with waste composition 36.33% (paper), 35.71% (plastic) and 14.54% (organic). That potential energy is equivalent to 7.19% of the total energy needed in Jakarta every month.

1. Introduction
In line with the increased number of population and their activities, the waste volume generated by urban activities has raised from time to time which gives rise to complex environmental issues such as water, air pollution or poor management of municipal waste in the Waste Disposal using landfill system[1]. The change in trend global of waste management has begun to reduce the use of landfill method focusing on Energy recycling of the waste in the form of RDF[2]. RDF not categorized as Hazardous and Toxic Waste may be originated from various sources, e.g. industrial, commercial, construction, mud or Municipal waste[3]. The waste in Commercial waste is generated from the locations of the trade center, market, shopping complex, hotel, office complex, restaurant and amusement center[4]. Commercial waste highly contains a mass fraction of inflammable materials (such as paper, wood, plastic, and textile) with significant potential in the recovery energy[5]. Municipal waste with high energy value characteristics may apply WtE concept (waste to energy) to be reused as energy through incineration process[6]

Samples are drawn over a period of days using Standard method SNI 19-3964-1994 to characterize mixed waste. the Sample prepared from a commercial Mall X. The total amount of waste to be sampled is 600 kg, around 100 kg each sample is sorted into 9 categories: paper, plastic, absorbent hygiene, wood, rubber, Styrofoam, glass, organic, metal, waste electronic and hazardous waste. Ultimate analysis test lab using American society for testing and material (ASTM) standard 3172-3175 and determination of calorific value using bomb calorimeter.
2. Research location

Jakarta is one of 26 autonomous provincial cities in Indonesia, accordingly in it’s known as Special Capital Region of (DKI) Jakarta. Under Law No.5 of 1974 on Basic Principles of Local Administration, Jakarta is designated as the Capital City of the Republic of Indonesia[7]. The total area of DKI Province Jakarta, as per Gubernatorial decree Number 171 of 2007 is 662,33 km$^2$ in land and 6997.5 km$^2$ at sea situated at 6º12’ South Latitude and 106º48’ East Longitude[8]. Central Bureau of Statistics (2018) suggested the total population number of DKI Jakarta in 2017 based on projection is 10.374.235 lives with the annual population growth rate of 0.94%[9]. DKI Jakarta has an important role in the economy, which includes services, trade, industry, tourism, etc. Under Law Number 29 of 2007 DKI Province is vested with special autonomy, including policy on administration or budget at province level[10]. The following table shows the economic structure of DKI Jakarta from the GDP distribution (gross domestic product) on the new base price in 2015-2018 semester 1.

\begin{table}[h]
\centering
\begin{tabular}{lccccc}
\hline
\textbf{Sector} & \textbf{2015} & \textbf{2016} & \textbf{2017} & \textbf{2018 semester 1} \\
\hline
Agriculture & 0.09 & 0.09 & 0.09 & 0.08 \\
Mining & 0.25 & 0.24 & 0.24 & 0.25 \\
Industry & 13.8 & 13.56 & 13.44 & 13.41 \\
Electricity, Gas, and Water & 0.35 & 0.33 & 0.34 & 0.38 \\
Construction & 13.3 & 12.88 & 12.81 & 12.51 \\
Trade, Hotel, and Restaurant & 16.6 & 16.52 & 16.97 & 17.23 \\
Transport and Communication & 15.55 & 15.76 & 15.95 & 15.87 \\
Services and Financial & 40.06 & 40.62 & 40.16 & 40.27 \\
Total & 100 & 100 & 100 & 100 \\
\hline
\end{tabular}
\caption{Economic Structure of DKI Jakarta in 2015-2018$^a$}
\end{table}

$^a$Source : Badan Pusat Statistik DKI Jakarta 2018[9]

The shift of economic structure in each sector is seen every year. The shift of economic structure in construction sector begins to decline from 13.3% to 12.51%. Shift economic structure in trade sector begins to rise from 16.6% in 2015 to 17.23% in 2018. The said growth is supported by the development of commercial areas, and improved facilities and infrastructures in trade, hotel, and restaurant activities. The development of commercial areas started in the 90s with the increased construction of shopping centers which was later integrated with the entertainment concept creating the concept of modern market or mall [11]
The change in value of gross domestic product (GDP) on constant price in commercial activities in Jakarta is shown in figure 1 GDP which has been mostly to reflect the economic rate. Especially in the trade sector, the value of GDP is 304.598 billion rupiah. The value raised significantly until 2017 to 408.987 billion. The increase in the GDP explains the rapid economic growth in Jakarta in the accumulated consumption, investment, or government expenditures in trade sector.

Syaukat (2007) suggested that as a Province Capital, Jakarta has the vision to become an international-class city that should have been furnished with various facilities and supporting infrastructures [12]. Yempormase (2013) suggested that Mall as one of the infrastructures in the commercial facility for commerce or trade of goods or services[13]. Aditinata (2013) stated that until 1989, there were 13 malls distributed all over Jakarta[14].

The distribution of malls in 1989 in the early stage of development in Jakarta was centralized in Central Jakarta and South Jakarta. These two locations were intended as a shopping area in the course of its development so that the distance among malls are not too far. Currently, the communication, informatics, and statistics of DKI Province Jakarta suggested that in 2017 there were 84 malls distributed all over Jakarta. The distribution of malls is shown in the figure below.

**Figure 1.** Change of GDP on Constant Price in Trade Sector

**Figure 2.** Distribution Map of Jakarta Malls in 1989
Syaukat (2007) suggested that in the RTRW DKI Jakarta 1985-2005 and 2005-2010 it was stated that the intended area of land for the commercial area was located in the core of the city and slightly distributed to the west part which was followed by settlement and green open space[12]. The tendency of centralized mall distribution in the map was to the south area which was 23 malls and central area 17 malls. In the west and east area, mall placement was quite evenly distributed one with another. In the north area, mall placement was inclined to be more centralized to some commercial areas.

3. Commercial areas

As per GR 112/2007 on management and facilitation of the traditional market, shopping center and modern store[15], explain:

- The market is defined as a place for sale and purchase of goods with more than one merchant whether called as a shopping center, traditional market, shopping complex, mall, plaza, trade center or other names.
- Shopping center is defined as a certain area consisting of one or more construction vertically or horizontally erected, sold or leased to the business players or self-managed for the trade of goods.

GR 81/2012 defines the classification of waste in the commercial areas as waste generated from a shopping center, market, shopping complex, hotel, office complex, restaurant and amusement center[16]. Thus, commercial areas have very broad coverage. One of the commercial areas is mall as one of the modern markets, besides the concept of supermarket or hypermarket. According to Aryani (2009) mall represents the typology of development from the concept of shopping center[17]. Nadine Beddington (1982) mentioned shopping center as a complete and planned shopping facility so that the existing shops may support one with another as recreational facilities to attract the visitors, in other words, an in interactive point where the public can shop at a place[18]. This is supported by Mayer (1993)suggesting shopping center as a group of retailers in one building jointly offering various products, consumer needs with shopping comfort made available like their homes or workplace [19]. Aditinata (2013) stated the development of shopping center is divided into 3 periods as follows[14]:

- First Period (1969-1970). During this period, Sarinah (1962) was constructed on an area measuring 21,000 m² and became the first modern shopping center in Indonesia
- Second Period (1971-1989). During this period, there were constructed at least 12 shopping centers such as duta merlin (1970), aldirodn plaza (1980), marketaya manggarai (1980), ratu plaza (1981), gajahmada plaza (1982) melawai plaza (1984) metro market baru (1985), harco market baru (1986) king’s plaza (1988), plaza barito (1988), pasar raya blok M (1989) and golden truly (1989). Total areas of the 12 markets totaled 222,300 m² which were constructed in 25 years.
- Third Period (1990-). The area constructed for shopping centers totaled more than 1,2 million m²
Aditinata classified the shopping center by the floor area. Each classification tends to offer different services based on target consumers[14]. The classification is as follows.

| Classification | Scale of Services | Floor Area Average (m²) |
|----------------|-------------------|-------------------------|
| Class A        | Global/regional   | >40.000                 |
| Class B        | Wide Area         | 15.000 s/d 40.000       |
| Class C        | Local             | <15.000                 |

Based on the classification by Aditinata, until 2017 there were more than 53 mall constructions in Jakarta which was focused on the floor area over 40.000. The construction was given the priority to Class A where the target services were global scale. Compared with the construction of the mall at a limited scale, 22 buildings and 4 buildings fell under Class C.

4. Commercial waste
The characteristics of commercial waste largely depend on waste management at the mall location. Commercial activities range from trade, purchase, and sale of goods/services at a major scale. Hence, in each mall, there are usually spaces designated for the food court, textile shopping area, book store or electronic store. Foodcourt is dominantly generating organic waste. Other shopping areas more dominantly generate paper and plastic waste from their sale and storage of goods. Some previous researches reviewed the topic of waste composition from malls in Indonesia. The respondents were Depok Town Square, Grand Trade Center Makassar, and Makassar Trade Center.

| Composition          | Percentage Waste Composition Mall (%) |
|----------------------|---------------------------------------|
|                      | Mal Depok Town Square a | Mal grand trade center Makassar b | Mall MTC Makassar c |
| Organic waste        | 70.89                      | 32.7                        | 28.7               |
| Paper                | 11.84                      | 31.58                       | 32.3               |
| Plastic              | 14.8                       | 29.69                       | 34.3               |
| Metal                | 0.33                       | 2.98                        | 1.4                |
| Stereofom            | 0.88                       |                             |                   |
| Glass                | 0.86                       | 2.03                        | 3.3                |
| Tekstile             | 0                          | 0.63                        |                   |
| Etc. (inert)         | 0.4                        | 0.39                        |                   |
| Total                | 100                        | 100                         | 100                |

a Sinaga, W I. 2016[20]
bSelintung, M. Rahim I R. Kelrey, M A. 2014[21]
cMahmuda A F. 2014.[22]

Depok Town Square as explained in the research by Sinaga (2016) showed that mall waste generated more organic waste than other waste characteristics [20]. Organic waste is generated from non-viable food, vegetables, meat and fruit waste from hypermart. The outcome from the research by Sinaga emphasized on the sample waste management especially waste from the mall foodcourt where Depok Town serves more fast food. In another research on mall waste, Selintung (2014)[21] and
Mahmuda (2014)[22] suggested that the quantity of organic waste is not far different compared with the paper or plastic waste. This also occurs in the ideal mall adopting 3R management of waste generated at the location.

One of the shopping centers is Mall X. This is located at Jl. Letjen Suprapto Kav. 1 Central Jakarta. Mall X is strategically located in the Central Jakarta in the main road intersection. The intended use of the land around the mall is surrounded by an office complex with a high mobility rate. The location is nearby settlement of kelapa gading and Cempaka Mas. Mall X has 12 floors for different functions with a total of 5000 shops.

The solid waste generated Mall X reached 27 tons per day which are heterogenic. 3R waste management is implemented at the location to reduce waste volume. 3R includes waste sorting, *black soldier fly*, composting and biopore, waste bank and incinerator. The remaining waste will then be disposed to the final waste treatment in Bantar Gerbang. The Composition of commercial waste in Mall X is as follows:

| Table 4. Waste Composition Mall X |
|----------------------------------|
| Composition | Percentage (%) |
|------------ |----------------|
| Paper/card | 36.33          |
| Plastic    | 35.71          |
| Textile    | 1.76           |
| Absorbent hygiene | 2.42   |
| Wood       | 0.86           |
| Rubber     | 1.24           |
| Styrofoam  | 5.03           |
| Kaca       | 1.12           |
| Organic    | 14.54          |
| Metal      | 0.33           |
| Electronic Waste | 0.56 |
| Hazardous Waste | 0.09   |
| Total      | 100            |

Table 4 shows that the waste composition in Mall X has less organic content compared with the inorganic. This has been caused by the fact that the waste has passed the 3R treatment stage at the location. The major composition is paper totaling 36.2% dominated by cardboard paper, and duplex. These two types of papers are used in the *packaging* process of merchandises to be sold at the mall. Another composition is plastic 35% which is dominated by beverage clear plastic, mica plastic, and multilayered plastic. Most plastic with selling value is also made use in the 3R management in the waste bank at the location. In forming Sample RDF, each material not used as RDF is not included in the sample composition. The rejected materials include absorbent hygiene, glass, iron, electronic waste, and hazardous and toxic waste.

5. Potential energy

Calor is one of the energy forms, where the value of calorific value is the amount of heat released during the incineration process per mass unit such as kcal/kg or kJ/kg. The amount of calorific value from the incineration process is comparable to the heat released from waste incineration. The energy in a waste can be calculated by bomb calorimeter, Dulong equation approach or other approaches using the balance of elements. Zahra (2012) made a comparison of the estimated amount of Energy...
value from various researches on each specific waste composition[23]. The energy value reference used is as follows:

**Table 5. Energy Value**

| Waste Component | Energy Value References | Compositio Wastemall X (%) | Estimated Energy Value |
|-----------------|-------------------------|----------------------------|------------------------|
|                 | Maria (2006)\(^a\)      | Antonopoulus (2010)\(^b\) | Maria (2006)\(^a\)      | Antonopoulus (2010)\(^b\) |
|                 | (Kcal/Kg)               | (Kcal/Kg)                  | (Kcal/Kg)              | (Kcal/Kg)                  |
| Plastic         | 6153.88                 | 7775.33                    | 42.67                  | 2626.06                    | 3317.99                   |
| Paper, Duplex   | 3536.63                 | 3773.04                    | 38.05                  | 1345.67                    | 1435.62                   |
| Textile         | 4809.43                 | 4116.91                    | 1.84                   | 88.65                      | 75.88                     |
| Rubber          | 6392.68                 | 6048.80                    | 1.30                   | 83.34                      | 78.86                     |
| Wood            | 1705.03                 | 1554.59                    | 0.90                   | 15.32                      | 13.97                     |
| Organic         | 1330.12                 | 1315.79                    | 15.23                  | 202.60                     | 200.42                    |
| Total           | 100                     | 4361.64                    |                        | 5122.74                    |

\(^a\)Maria&pavesi (2006)\(^24\)

\(^b\)Antonopoulus (2010)\(^25\)

Energy value generated by the waste in mall X ranged from 4361 kcal/kg to 5122 kcal/kg. The energy value is generated from calculating the composition multiplied with the Estimated Energy Value of each waste. The energy value is also estimated by designing the Waste composition to be made as RDF (table 6). Energy value is identified through bomb calorimeter. The result of the comparison is presented in the following table

**Table 6. Comparison of Energy Value Using Bomb Calorimeter**

| Energy Value | kcal/kg |
|--------------|---------|
| Sampel RDF 1 | 4558.24 |
| Sampel RDF 2 | 3455.06 |
| Sampel RDF 3 | 4708.18 |
| Sampel RDF 4 | 4586.32 |
| Sampel RDF 5 | 5037.45 |
| Sampel RDF 6 | 4895.18 |
| Average      | 4540 ± 562 |

Table 6 shows that the potential of waste in mall X ranged from the Energy value Average 4540 ± 562 kcal/kg waste. The result of bomb calorimeter in 6 RDF Samples rests between the range of the approach through Maria [24] and Antonopoulus [25] references.

**Table 7. RDF Ultimate Analysis**

|           | Carbon | Hydrogen | Oksigen | Nitrogen | Sulfida |
|-----------|--------|----------|---------|----------|---------|
|           | %      | %        | %       | %        | %       |
| RDF 1     | 41.33  | 4.99     | 31.27   | 2.77     | 0.18    |
| RDF 2     | 27.22  | 3.89     | 59.28   | 1.84     | 0.21    |
| RDF 3     | 32.2   | 4.88     | 41.21   | 1.18     | 0.17    |
| RDF 4     | 34.29  | 4.92     | 28.22   | 1.99     | 0.13    |
In comparison, the average result of the ultimate analysis on Sample RDF mall X, there was identified C (36.91%), H (5.14%), O (37.94%), N (1.96%), S (0.19%). By using Dulong equation, there was identified Energy value of 3123.90 kcal/kg. The standard use of alternative fuel in ITP cement factory is above 2500 kcal/kg. This causes the mall waste potential meets the standard of alternative fuel to coal in the cement industry. Referring to the planned regular delivery of waste from mall X of 20 ton per day. Data of Energy used in estimating the Potential Energy using Energy value generated from the bomb calorimeter, because it has lower standard deviation than average energy generated by Dulong’s equation with chemical composition. With average Energy value of 4540 ± 562 kcal/kg from bomb calorimeter, the waste generated is 90.801.484 kcal/day

6. Potential commercial waste in Jakarta
The projection approach is based on the land area in each mall. It is assumed that the condition among the malls is typical in Jakarta so that waste from all malls in Jakarta approached the composition of malls at Mall X. The potential value is shown in the following table

| Table 8. Potential Waste Energy from the Malls in Jakarta |
|----------------------------------------------------------|
| Unit | Value |
|-----------------|--------|
| Potential Energy Value Mall X | Kcal/Kg | 4540.07 ± 562.4 |
| Disposal form Mall X | Ton/day | 20 |
| Mall X Land Area | m² | 180608 |
| Mall Potential | Kcal/(day. m²) | 678.72 ± 84.08 |
| Total Mall Area | m² | 8014525.44 |
| Potential Energy from Waste Malls in Jakarta | Gcal/day | 5439.61 ± 673.83 |
| | GWh/month | 189.78 ± 23.51 |

The amount of potential Energy value from mall X is 4540.07 ± 562.4 kcal/kg. With mall X land area of 180608 m², the Mall Potential Energy in Jakarta is 678.72 ± 84.08 kcal/(kg.m²). The result of the mapping of malls in Jakarta, the land area is 8014525.44 m². Based upon the said result, it is known that the amount of Potential Energy of all malls in Jakarta is 5439.61 ± 673.83 Gcal/day. With the conversion of one Energy Unit kilocalorie as equivalent to 0.001163 kilowatt-hours, the estimated Potential Energy at all malls in Jakarta is 189.78 ± 23.51 GWh/month. The Potential Energy will be compared with the required amount of power in Jakarta
Figure 4. Total Amount of Power (GWh) Ready-to-Sell and Sold in Jakarta

*Source: Badan Pusat Statistik DKI Jakarta 2018*

Data from the Central Bureau of Statistics shows that the Average Energy sold was 2636.92 GWh per month. The value represents the need for Energy in Jakarta from consumption of PLN Electricity. The users include domestic, business, industry, office complex, etc. With the Potential Energy at all malls in Jakarta of 189.78 ± 23.51 GWh/month, the potential value can fulfill 7.19 % of the total energy needs per month.

7. Conclusion

The presented study shows that the Utilization of commercial waste energy into renewable energy sources is the solution to the problem of solid waste generation in Jakarta as well as sources of energy available for Jakarta. This condition will be achieved if there is ongoing cooperation between the mall manager and the cement industry in utilizing waste as an alternative fuel.

References

[1] Setiyono and Sri W 2002 Sistem pengelolaan sampah kota di Kabupaten Bekasi – Jawa Barat J. teknologi lingkungan 2(2) 194-198.

[2] Sapuay GP 2016 Resource Recovery through RDF : Current Trends in Solid Waste Management in the Philippines J. procedia environmental sciences35 464-473.

[3] Garcés D, Diaz E, Sastre H, Ordóñez S and González-LaFuente JM 2015 Evaluation of potential of different high calorific waste fractions for the preparation of solid recovered fuels J. waste management47 164-173.

[4] Republic of Indonesia2012 PP Nomor 81 tentang pengelolaan sampah rumah tangga dan sampah sejenis sampah rumah tangga(Repulik of Indonesia)

[5] Nasrullah M, Vainikka P, Hannula J and Hurme M 2015 Elemental balance of SRF production process : solid recovered fuel produced from commercial and industrial waste J. fuel1451-11.

[6] Bessi C, Lombardi L, Meoni R, Canovai A and Corti A 2015 Solid recovered fuel : an experiment on classification and potential applications J. waste management 47184-194

[7] Republic of Indonesia 1974 UU Nomor 5 tentang pokok-pokok pemerintahan di Daerah(Repulik of Indonesia)

[8] Republcof Indonesia 2007 Surat Keputusan Gubernur DKI Jakarta Nomor 171 tahun 2007 tentang penataan batas dan luas wilayah kelurahan di Provinsi Daerah Khusus Ibukota Jakarta(Republik of Indonesia)

[9] Central bureau of statistics DKI Jakarta 2018Provinsi DKI Jakarta Dalam Angka(Jakarta : Badan Pusat Statistik)

[10] Republik of Indonesia 2007UU Nomor 29 tentang pemerintahan provinsi daerah khusus Ibukota Jakarta sebagai Ibukota Negara Kesatuan Republik Indonesia(Republik of Indonesia)
[11] Prasojo T 2010 *Shopping mall di Jakarta Barat* (Semarang : Universitas Diponegoro)
[12] Syaukat SF 2007 *Persebaran Gedung Perkantoran di DKI Jakarta* (Depok : Universitas Indonesia)
[13] Yempormase AA 2013 *Jogja City Walk Sebagai Kawasan Ciri Khas Wisata Kuliner dan Fashion yang Berkonsep Green Architecture di Yogyakarta.* (Yogyakarta : Universitas Atma Jaya)
[14] Aditinata 2013 Penjelmaan pusat perbelanjaan sebagai ruang public semu J. *planesa*4(2) 79-85
[15] Republic of Indonesia 2007 *PP Nomor 112 tentang Penataan dan Pembinaan Pasar Traditional Pusat Perbelanjaan dan Toko Modern* (Republik of Indonesia)
[16] Republic of Indonesia 2012 *PP Nomor 81 tentang Pengelolaan sampah rumah tangga dan sampah sejenis sampah rumah tangga* (Republik of Indonesia)
[17] Aryani, DI. Perubahan makna dan presepsi masyarakat di kota besar terhadap ruang public (studi kasus : pusat perbelanjaan di kota bandung). *Journal Ambiance*, 2009; 2(2): 95-106
[18] Beddington N 1982 *Design for shopping centers* (London : butterworth scientific)
[19] Mayer dan Wilkinson 1993 *A cluster of retail outlets under a single roof that collectively handle a varied assortment of goods, satisfying most of the merchandise needs of consumers within convenient traveling time of their homes or places of work* (New jersey : prentice hall inc)
[20] Sinaga WI 2016 *Perencanaan Pengelolaan Sampah Berdasarkan Timbulan dan Komposisi Sampah di Mal Depok Town Square* (Depok : Universitas Indonesia)
[21] Selintung M, Rahim IR and Kelrey MA 2014 *Pengelolaan Sampah di Mall Makassar Trade Center (MTC) Makassar* (Makassar : Universitas Hasanudin)
[22] Mahmuda AF 2014 *Pengelolaan sampah di mal GTC Makassar* (Makassar : Universitas Hasanudin)
[23] Zahra F 2012 *Analisa Nilai Kalor Sampah UPS Depok Menjadi Refuse Derived Fuel (RDF)* (Depok : Universitas Indonesia)
[24] Maria FD and pavesi G 2006 RDF to energy plant for a central Italian region SUW management system : energetic and economical analysis *J. Applied Thermal Engineering*6(11-12)1291-1300.
[25] Antonopoulous IS, Karagiannidis A and Kalogirou E 2010 Estimation of municipal solid waste heating value in greece in the frame of formulating appropriate scenarios on waste treatment *Pro. 3rd Int.Symp. on energy from biomass and waste* (Venice : Aristotle University of Thessaloniki).

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