"Waste to Energy" System in Shanghai City

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1. Introduction

In the past fifteen years, the economics of China has maintained continuously fast growing, as shown in Figure 1. At the mean time, China has quickly urbanization, reflecting from the continuous increment of urban population. As one of results, the production of municipal solid waste (MSW) in China has also been quick rising. According to China Statistical Yearbooks, the produced MSW in 2004 was 155.1 million tons, which is more that twice as that in 1990 (Figure 1). Furthermore, only about 52% of MSW in 2004 has been disposed, in which, 44% was sanitary landfilled, 5% was composted, and 3% was incinerated. The remained 48% MSW was just simply dumped on the open land or was not subjected any treatment, which has caused several environmental and healthy hazards, such as odors, groundwater pollution, and spread of diseases by flies, rats, animals or human scavengers.

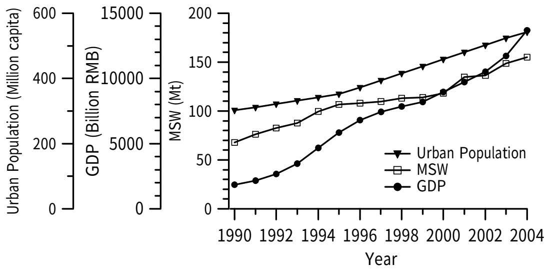

Fig. 1. The yearly growth of urban population, GDP, and MSW in China from 1990 to 2004.

On the other hand, the production and consumption of energy has become a deep problem in China recently. As predicted by Komiyama and coworkers[2], the total energy demand will reach 2133 Mtoe in 2030, which is more than twice as that in 2002 (1026 Mtoe). Actually, according to China Statistical Yearbook, China has become the top second country in world for energy production and consumption in 2004. The total production of energy in 2004 was 1.846 billion ton of standard coal, only covered over 90% of total consumption. The remained 10% energy need was dependent on the oversea markets. In 2004, the net crude oil import in China was 117 million tons, accounting for 6.31% of the worldwide trade. Furthermore, the production of energy in China is mainly dependent on coal, which has brought a deep pollution in China.

MSW is composed of lots of organic carbon, which contains plenty of potential energy. In fact, the incineration of MSW produces lots of heat, which can be used for power generation. Alternatively, MSW upon landfill, can decompose to generate landfill gas (LFG), in which 40-60% volume is methane. In the developed countries, such as Japan, U.S.A., and Europe, utilization of MSW for generation of electric power or heat recycling has been recognized as an important MSW disposal methodology due to its several benefits: (i) reducing the depletion of the earth's limited natural resources; (ii) reducing pollution produced by discharging untreated waste; (iii) directly and indirectly saving energy. Although Chinese government and other social organizations have already devoted more and more attention on MSW reutilization, the level of MSW disposal is still very low. Most MSW energy potential has been wasted in the past. Therefore, there is an urgency to investigate and establish an efficient system to recover the potential energy of MSW in China.

Since it is difficult to carry out the investigation on the whole country of China, here we choose Shanghai city as the investigation object (Figure 2). Shanghai city is one of the top leading metropolises in China. The above mentioned problem is much more serious in Shanghai.

Fig. 2. The location of Shanghai city

2. Investigation methodology

1. Current situation study, including the collection of the basic data of Shanghai city.

2. Prediction of MSW amount and composition until 2030.

3. Evaluation of energy recovery by current MSW disposal system.

4. Optimization through model simulation of the MSW management system in 2030, aiming at the maximization of energy recovery from waste.

5. Based on the case study, proposal of an efficient MSW manipulation system for Shanghai

in 2030.

Life Cycle Assessment (LCA) is used as tool to analysis the recovery energy. The LCA boundary is explained in Figure 3.

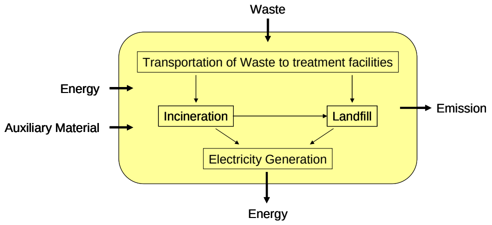

Fig. 3. LCA boundary

0-1 programming problem has been applied in the model simulation to solve the facility location problem in the future MSW management sytem.

3. Results and discussion

(1) Prediction of MSW generation the future

The prediction of MSW is based on the GDP value of Shanghai city. GDP data can partially reflect the real population in Shanghai because the number of employees from out of Shanghai would increase if the economy of Shanghai is more active. GDP is also related to the level of people daily life. Actually, the data of MSW amount are well fitted with GDP from 1995 to 2005 by using the following equation:

$$MSW = 1963.78 - 3129.02 \times \log GDP + 1093.78 \times (\log GDP)^2$$

Where $R2 = 0.99$, the unit of MSW is kt, and the unit of GDP is 10^8 RMB.

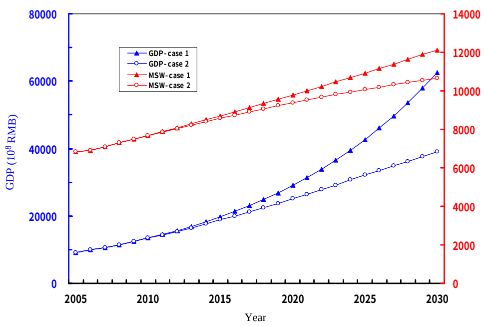

Fig.4. Prediction of MSW in Shanghai

Thus, The MSW was predicted by adopting GDP growth rate as shown the following two cases:

Case 1: The economy of Shanghai is proposed to maintain a constant growing fashion with a constant rate of 8%.[3]

Case 2: The growing rate for GDP is 8% in the period of 2006-2010, then decrease 1% every 5 years. The average GDP growing rate over 2006-2030 is 6%, consistent with that reported by Komiyama, et al.[2]

(2) The composition of MSW in Shanghai

The composition of MSW is important factor. The change of composition of MSW in Shanghai is displayed in Figure 7. The data show that the content of food in MSW decreased gradually, while that of plastics and paper exhibited an increasing trend.

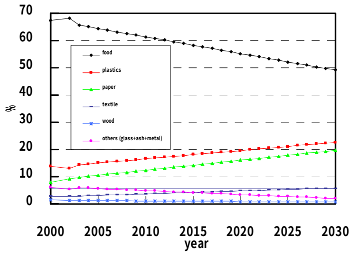

Fig. 5. The change of MSW composition in Shanghai from 1990 to 2002.

(3) The MSW treatment in 2005 in Shanghai

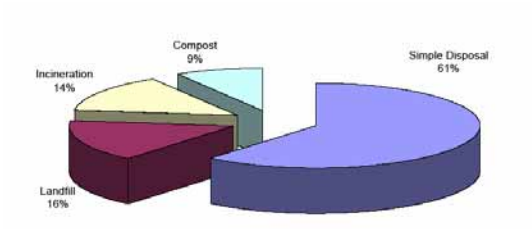

Fig. 6. Management of MSW in 2005

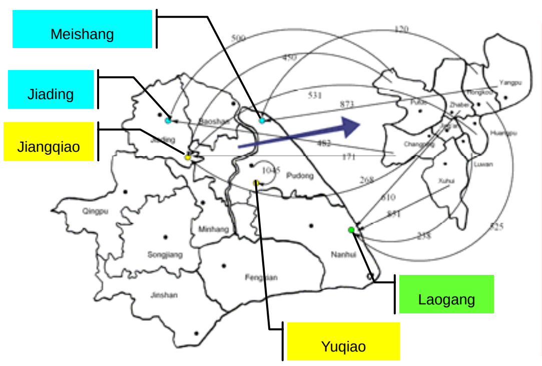

Fig. 7. Location of MSW management facilities and mass flow in 2005.

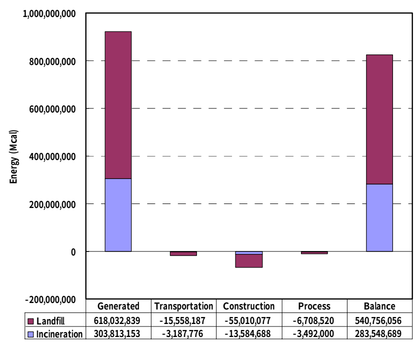

Fig. 8. Energy recovery in 2005.

(4) The MSW treatment in 2030 by model simulation

a) Principle:

① 18 districts as MSW generation source.

② Only 9 suburbs can build new facilities, either incineration, or landfill. Total possible facilities is 18. Current facility: 3

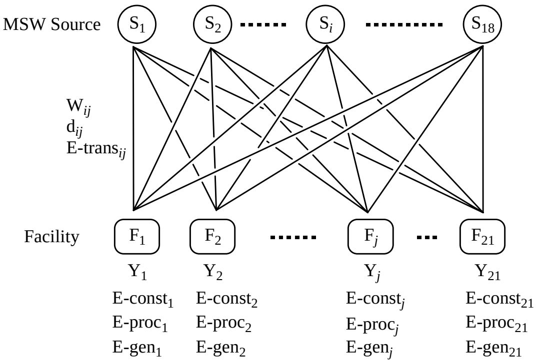

Fig. 9. Simulation Scheme

Maximization of Energy Recovered]:

$$TotalEnergy = \sum_j E\text{-}gen_j - \{\sum_i \sum_i E\text{-}trans_{ij} + \sum_j E\text{-}proc_j + \sum_j E\text{-}const_j\}$$

[Conditions]:

$$S_i = \sum_j x_{ij} \quad (i = 1, 2, \ldots, 18;\ j = 1, 2, \ldots, 21)$$

$$x_{i,j} \geq 0 \quad (i = 1, 2, \ldots, 18;\ j = 1, 2, \ldots, 21)$$

$$\sum_i x_{ij} \leq Q_j \quad (i = 1, 2, \ldots, 18;\ j = 1, 2, \ldots, 21)$$

$$Y_j = \begin{cases} 0 & \text{Facility } j \text{ should not be built.} \\ 1 & \text{Facility } j \text{ should be built.} \end{cases} \quad (j = 1\text{-}18)$$

$$Y_j = 1 \quad (j = 19, 20, \text{ and } 21)$$

$$\sum_j Y_j = p \quad (j = 1, 2, \ldots, 21)$$

where:

Si : total MSW mass at source i (t/d)

xij : the mass of MSW transported from source i to facility j (t/d)

dij : the transportation distance from source i to facility j (km)

p: the number of built facilities

Qj: The handing capacity of facility j (t/d)

E-genj: Energy generated at facility j per day (Mcal/d)

E-transij: Energy consumption for transportation from source i to facility j (Mcal/d)

E-procj: Energy consumption for treatment at facility j, (Mcal/d)

E-constj: Energy consumption for construction of facility j (Mcal/d)

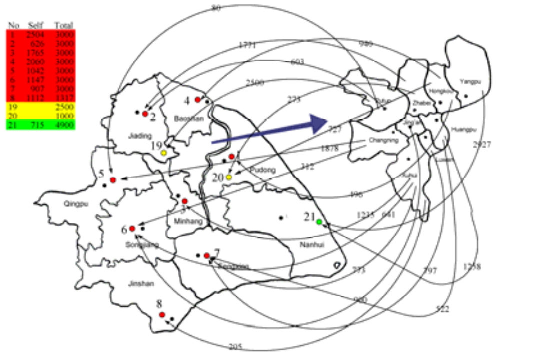

Fig. 10 Location of new plants and mass flow under Scenario 1

b) Scenario study:

Scenario 1: Capacity of incineration plant ≤ 3,000 t/d; Capacity of landfill plant ≤ 5,000 t/d.

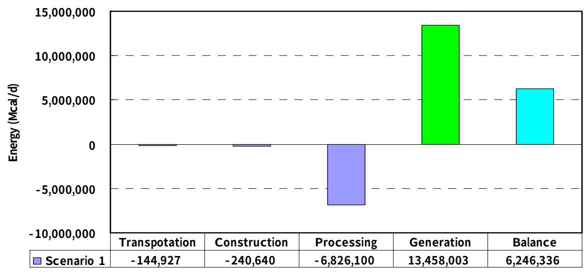

Fig. 11. Total Energy for each disposal process in Scenario 1

Scenario 2: Capacity of incineration plant ≤ 5,000 t/d; Capacity of landfill plant ≤ 5,000 t/d.

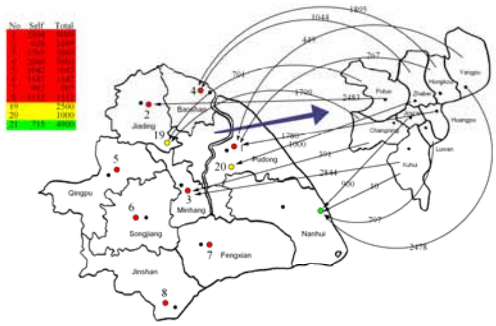

Fig. 12. Location of new plants and mass flow under Scenario 2

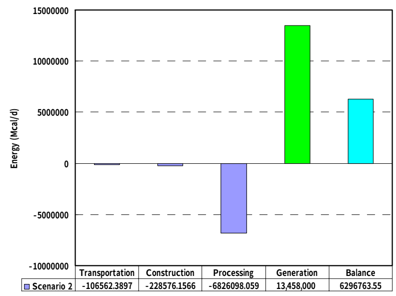

Fig.13. Total Energy for each disposal process in Scenario 2

Scenario 3: Capacity of incineration plant ≤ 8,000 t/d, Capacity of landfill plant ≤ 5,000 t/d.

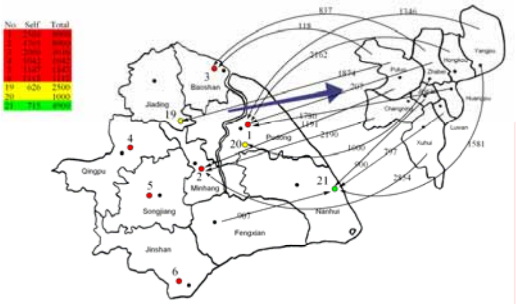

Fig. 14. Location of new plants and mass flow under Scenario 3

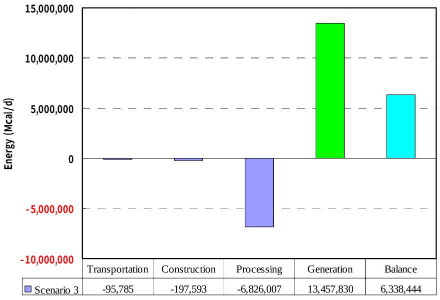

Fig. 15. Total Energy for each disposal process in Scenario 3

Scenario 4: Plastics is separated and should be incinerated; Capacity of incineration plant ≤ 8,000 t/d; Capacity of landfill plant ≤ 5,000 t/d.

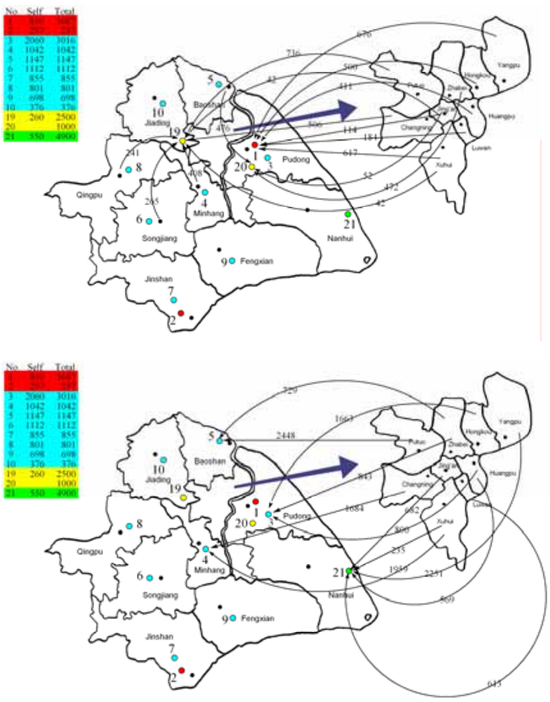

Fig. 16. Optimized mass flow in Scenario 4

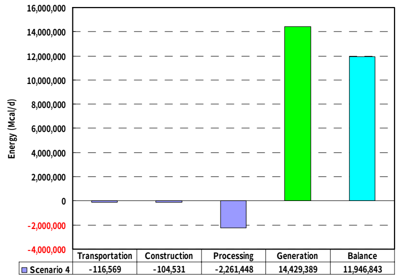

Fig. 17. Total *Energy for each disposal process in Scenario 4.*

c) Comparison:

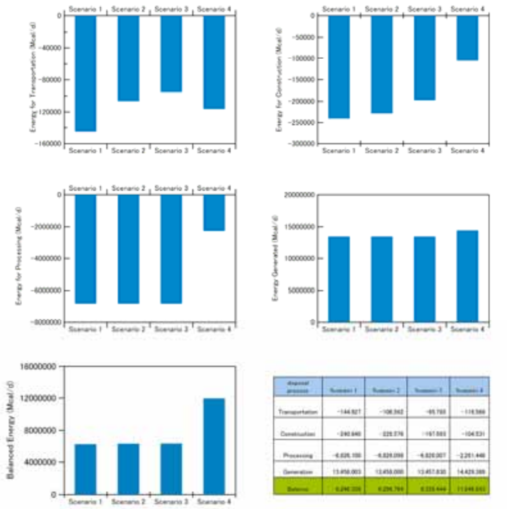

Fig. 18. *Comparison among scenarios*

A larger capacity of incineration reduces with both the transportation energy and construction energy.

Separation of plastics greatly benefits the extraction energy from waste: improve the energy generation, reduce the energy consumption for construction and processing.

4. Future direction

(1) Including cost and environmental index

(2) Including composting.

Reference

1. China Statistical Yearbooks, 1996-2004.
2. R. Komiyama, P. Zhang, Z. Lu, Z. Li, and K. Ito, China's long-term energy outlook for 2030 by 31 provinces based on compiling provincial statistics and developing an economic model, the 22nd Conference on Energy System, Economics, and Environment, 285-288.
3. L. Kuijs, T. Wang, China's pattern of growth: moving to sustainability and reducing inequality, World bank China office research working paper No.2, pp.10.