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Comprehensive Evaluation of The Public Policy for Making Solidified Fuel and Compost Out of Waste

-Case Study for Nogi Town, Tochigi Prefecture, JAPAN-

by

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Abstract:

Centering on the policy of the production of solidified fuel and compost in Nogi Town, Tochigi Prefecture, Japan, an evaluation of this policy was carried out from the standpoint of garbage reduction and recycling. With respect to the reduction in amount, a theoretical model was set, upon which an empirical analysis of the effect of a reduction in the amount of waste through an analysis of the primary factor of the structure of the production of waste and its disposal was carried out. With regards to recycling, an analysis of a simulation of RDF production and the effect of the amount of water contained in the raw waste was carried out. Furthermore, an analysis was performed in relation to the 'Container and Packaging Recycling law', to include the influence that things such as PET bottles and other plastics have on the production of RDF.

It was indicated that the policy for the production of RDF and compost in Nogi Town, Tochigi Prefecture, had the effect of a reduction in the amount of waste due to the simultaneously implemented of a system for separate collection of combustible waste and kitchen waste. In addition, it was found that when the amount of water contained in the raw waste is high, there is a large effect on the production of RDF such as an increase in the cost of the drying process and a decrease in the amount of RDF produced.

Keywords: RDF, compost, reduction, recycling, policy evaluation

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1. Introduction

Waste, with the diversity of lifestyle and the change in the industrial structure as a background, has been increasing in amount and changing in quality.   It has been difficult to construct waste treatment facilities and secure final places of disposal.   Therefore, many local municipalities are coming up against a critical situation with respect to this waste problem.

This is not limited to Japan only, as other countries such as America are facing the same problem. In America, as one example of a policy to cope with the problem, the use of hydrogen and ethanol, that comes from garbage collected by local municipalities, for the operation of buses is being examined. This has been evaluated as being more friendly to the Earth, from the life cycle aspect, than the conventional diesel engine[1].   On the other hand, at the Recycling Center located in Nogi Town, Tochigi Prefecture, that has been in full operation since December of 1992, the policy of producing solidified fuel (RDF) from combustible garbage and compost from kitchen waste has been implemented.   Due to this policy, this local municipality is thought to be quite advanced in terms of waste treatment since the recycling rate has reached 44%[†] (actual results from 1994).   Therefore, in this research the aforementioned waste treatment policy for RDF and compost in Nogi Town, Tochigi Prefecture will be concentrated on where an evaluation of the policy, from the standpoint of a reduction in waste and recycling, will be carried out.   This will provide a means for considering what the waste treatment policy should be from now on.

2. Outline of Nogi Town, Tochigi Prefecture, Japan

Nogi Town is located in the furthest southern part of Tochigi Prefecture, 70 km from the Japan's Capital, Tokyo and 40 km away from the Prefectural Capital, Utsunomiya, which is connected by the Japan Railway (J.R.) Tohoku main line and National root 4 Highway, respectively.   As of October 1, 1995, the population was 26,491, which was comprised of 7763 households.   Looking at the condition of waste treatment, from 1992 waste was not handled by the one way method of disposal, incineration and landfilling, but with it being transported to the facilities that produce RDF and compost, thus showing that recycling is being strongly promoted.
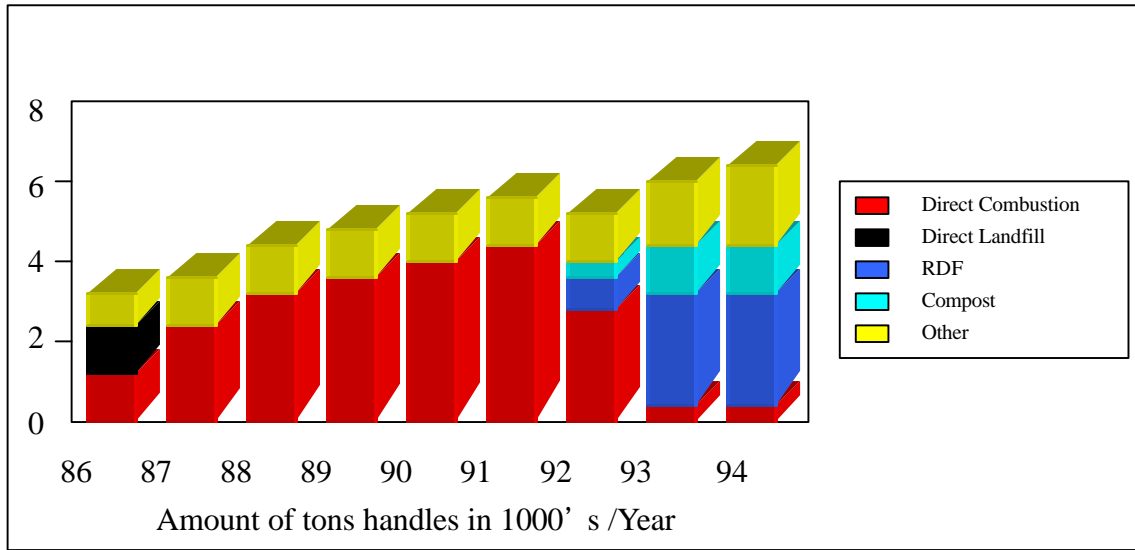
Figure 1: The Condition of Waste Treatment in Nogi Town, Tochigi Prefecture

Source: Reference 2) Tochigi Prefecture

3. Evaluation of the Policy Concerning Waste Reduction

3.1 Setting of the Theoretical Model

With reference to the 'Yasuda-Oshima 3 Goods Model', a theoretical model will be constructed by using three goods which include: (1) Waste treatment service (in Nogi Town, Tochigi Prefecture, non-combustible waste and large waste), (2) resource collection service (in Nogi Town, Tochigi Prefecture, combustible, raw, and recyclable waste), and (3) composit goods (other goods)[3)4)].

(1) Derivation of the Demand Curve Using the 3 Goods Model

For the rational behavior of the household budget, the utility function is made the largest by the consumption of the waste treatment service x_1, resource collection service x_2, and synthetic goods.

$$U=U\ (x_1,x_2,x_3) \qquad \text{But, } x_1,x_2,x_3>0 \tag{1}$$

If the prices of 3 Goods are given by P_1,P_2,P_3 and the household income is given by I, then the budget constraint formula for the household budget is shown as follows:

$$I=\sum P_iX_i= P_1X_1 + P_2X_2+ P_3X_3 \tag{2}$$

Expression (3) is defined by the waste production function of waste for the combined by-product that inevitably occurs upon the consumption of synthetic goods.

$$x_4=f(x_3) \tag{3}$$

The waste that is produced (x_4) is handled by either the waste treatment service (x_1) or the resource

collection service (x_2) and is given by expression (4).

$$x_1 + x_2 = x_4 \qquad (4)$$

Also, as a utility function, the CES (Constant Elasticity of Substitution) type function is defined. If it is assumed that the linear function of the synthetic goods is the amount of waste produced, then expressions (5) through (8) apply.

$$MaxU = [áX_1^{-ñu} + âX_2^{-ñu} + (1-á-â)X_3^{-ñu}]^{-1/ñu} \qquad (5)$$

s.t. $\quad P_1X_1 + P_2X_2 + P_3X_3 = I \qquad (6)$

$\quad X_4 = a + b\,X_3 \quad (a>0,\ b>0) \qquad (7)$

$\quad X_1 + X_2 = X_4 \qquad (8)$

To get the demand function x_1^0 using the utility maximization model and the Lagrange function the following expression is used:

$$X_1^0 = (I/P_3 + a/b)/[(P_1/P_3 + 1/b) + (P_2/P_3 + 1/b)(âP_1/áP_2)^{1/(ñu+1)}] \qquad (9)$$

Similarly, the demand function for x_2^0 is given by:

$$X_2^0 = (I/P_3 + a/b)/[(P_2/P_3 + 1/b) + (P_1/P_3 + 1/b)(âP_1/áP_2)^{-1/(ñu+1)}] \qquad (10)$$

(2) Analysis of the Effect of Price

The effect of the price towards the amount of demand of a separated collection service x_1 at a price p_1 for a separated collection service will be analyzed. Equation (9) is partially differentiated to calculate p_1.

$$\partial X_1^0/\partial P_1 = [1 + (1/(ñu+1))(P_2 + 1/a)(âu/áP_2)^{(1/(ñu+1))} P_1^{(-ñu+1)}][-(I + a/b)/\{(P_1 + 1/b) + (P_2 + 1/b)(âP_1/áP_2)^{1/(ñu+1)}\}^2] < 0 \qquad (11)$$

For this the sign is set at minus. Considering this, it was found that there is a decrease in the amount of demand for the separate collection service due to an increase in the price of the separate collection service. Also, the effect of the price towards the amount of demand x_2 for the resource collection service, at a price of the resource collection service p_2, similarly has $\partial x_2^0/\partial p_2 < 0$.

Next, the effect of the price towards the amount of demand x_2 for the resource collection service at the price of the resource collection service p_1, will be analyzed.

From

$$\partial X_2^0/\partial P_1 = \{1/P_3 - (1/(ñu+1)P_1)(P_1/P_3 + 1/b)\}(âP_1/áP_2)^{-1/(ñu+1)}[-(I/P_3 + a/b)/\{(P_2/P_3 + 1/b) +$$

4

$(\mathbf{P}_1/\mathbf{P}_3+ \mathbf{1}/b)(\hat{a}\mathbf{P}_1/\acute{a}\mathbf{P}_2)^{-1/(\tilde{n}\ast1)}\}^2]$ (12)

We can obtain $x_2{}^0/$ $p_1>0$ if

$1/\mathbf{P}_3-[(1/(\tilde{n}\ast1)\mathbf{P}_1)(\mathbf{P}_1/\mathbf{P}_3 +1/b)]<0$ (13)

That is to say, from $(\tilde{n}\ast-1)$, in the case that $\tilde{n}\ast0$, $p_1/p_3>b\tilde{n}u$ and in the case that $-1<\tilde{n}\ast0$, $p_1/p_3<b\tilde{n}u$ it can be said that $x_2{}^0/$ $p_1>0$.   From this there exists a substitutional goods relationship between the resource collection service and the waste treatment service.

3.2 Analysis of Waste Production and the Primary Factor of its Discharge Structure

   With respect to the theoretical model analyzed in the previous section, from the standpoint of waste behavior in terms of the family budget, an empirical analysis of waste production, the primary factor its discharge structure and the effect of a decrease in the amount of waste will be carried out in this section using data from Nogi Town, Tochigi Prefecture and Haibara Town, Nara Prefecture.

   The waste behavior in terms of the family budget is shown in figure 2.   Supposing that Y represents the family budget activity, X represents the amount of goods that must be purchased to maintain Y, W represents the amount of waste disposed of, E represents the environmental main factor surrounding the family budget, S_K represents the purchase system of goods, and S_G represents the waste treatment policy of the local self governing body, the following expressions will be assumed. In this research, expression (2) will be analyzed.   The variables are assigned for each in expression (2).

$X =f_1 (Y, S_K, E)$ ------------   (1)
$W=f_2 (Y, S_K, S_G, E)$ -------   (2)

The variable are explained as follows: Variables:

W➔ Amount of waste collected per person per day (g/person   day): SYU

Y➔ Income per person (Millions of Yen/person): SYO

S_K➔ Retail industry sales amount per area (Millions of Yen/m^2): HAN

S_G ➔ RDF and compost policy dummy (0 until 1991 and 1 on and after 1992): SEI

E ➔ Environmental primary factor (not considered in this research)

Purchase System (S_K)   Policy (S_G)

$\downarrow$ $\downarrow$

Amount of goods purchased $\longrightarrow$ Activity of household $\longrightarrow$ Amount of waste

(X)   budget (Y)   disposed (W)

(Consumption activity)

(Leisure activity, etc.)
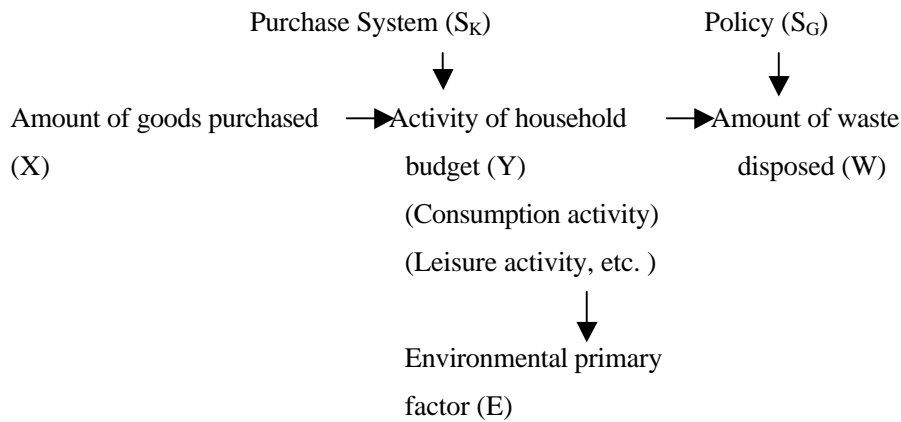
$\downarrow$

Environmental primary

factor (E)

Figure 2: Waste Behavior in Terms of the Family Budget

Source: Revision of the figure from Kitabatake(1981)

(1) Analysis of the Primary Factor Related to the Public Policy in Nogi Town, Tochigi Prefecture

Data from 1986 to 1995, comprising a total of ten, will be used[†] . Also, with respect to the amount of income and the retail industry sales amount, the actual value is calculated by dividing by the price index for 1986, which has been set at 100. For the policy dummy, for the purpose of analyzing the difference of having or not having a policy for RDF and compost production, an intercept dummy and coefficient dummy will be used.

The source for the data is given in Table 1. Upon examination, the correlation coefficient between SYO and HAN was 0.931, which suggests that a multi-collinearity had occurred. The R^2, adjusted R^2 and t-value of the individual variables are high therefore the following regression equation will be used for analysis.

SYU=19.480 + 598.496HAN + 255.915SEI - 329.866HAN*SEI   (3)

     (0.298)   (7.467)**   (1.684)   (-2.295)*

R^2=0.934, Adj R^2=0.902, (   ) t value.

**: 1% Level of Significance

*: 5% Level of Significance

6

Table 1: Data Source

Variable	Data	Name of Document	Location of Document Source
SYU	Amount collected, Population	Enterprise Outline, Transition of Nogi Town	Tochigi Prefecture Environmental Sanitation Maintenance Section, Nogi Town Office Planning Finance Section, Planning Coordination Committee
SYO	Income amount	Condition of Taxes in Cities, Towns and Villages	Tochigi Prefecture General Affairs Section Local Section
HAN	Retail Industry Sales Amount, Retail Industry Sales Area, Price Index	Commercial Statistics Chart (City, Town and Village Edition), " Price Index Annual Report	Ministry of International Trade and Industry Cabinet Minister Secretariat Survey Statistics Division, " Bank of Japan Survey Statistics Section

† For the amount of garbage collected, it is assumed that a one two ton truck carried XX tons up to 1985. From 1986 the method of weighing is different (by truck scale).

(2) Analysis of the Main Factor Related to Public Policy in Haibara Town, Nara Prefecture

   For the purpose of comparison, the data from Haibara Town, Nara prefecture will be used to make a similar analysis. In Haibara Town, Nara Prefecture, since 1987, separate collection for five types of waste has been carried out since 1987, which include: combustible waste, plastics, metals, glasses and large waste. From October of 1990, the policy to make RDF out of combustible waste has been in effect.

   At the time of analysis, the variable used are the same as for Nogi Town, Tochigi Prefecture. Nine pieces of data, which are from the years 1987 until 1995, will be used. With respect to the data source for amount of waste collected and population, documents from the Haibara Town, Nara Prefecture Waste Center will be used. Information on Income was obtained from a hearing at the Haibara Town Office. Everything else is the same as for Nogi Town, Tochigi Prefecture. The results are given as follows:

SYU=69.435 + 304.090SYO - 87.592HAN   (4)

(2.263)*   (14.361)**   (-1.889)

R^2=0.940, Adj R^2=0.910, (   ) t value.

**: 1% Level of Significance,

*: 10% Level of Significance

The correlation between SYO and HAN was 0.771 which suggests that multi-collinearity had not occurred.   Even with the input of the RDF Policy Dummy (0 until 1989 and 1 on and after 1990) and subsequent analysis, the t-value was 0.01.   Therefore it was thought that there was no influence by the Dummy variable, so this was not added into the analysis for Haibara Town, Nara Prefecture.

(3) Examination of the Analysis of Primary Factor

By comparing the policy of Nogi Town, Tochigi Prefecture and Haibara Town, Nara Prefecture, the following was understood.   At Nogi Town, Tochigi Prefecture, when the policy for making RDF and compost was carried out, the separate collection of combustible waste and kitchen was also begun at the same time.   On the other hand, there was no change in the separation method at Haibara Town, Nara Prefecture; the policy was a shift of the treatment of combustible waste away from incineration towards the making of RDF.

From the above, the reason that the dummy policy was effective and that there was a reduction in the amount of waste collected in Nogi Town, Tochigi Prefecture, was not due to the implementation of the policy for making RDF and compost.   Rather it is thought that this is due to the effect of the beginning of simultaneous separate collection of combustible waste and kitchen waste.

3.3 Empirical Analysis of the Effect of a Reduction in Waste

With respect to equation (3), using the concept of elasticity, each of the primary factors has been changed by 1% and the amount of change in the amount of waste disposed to the theoretical value that will become the standard is sought[6] (Table 2).

In Table 2, since the RDF and compost policy was not in effect from 1986 until 1991, the influence that the sale price and the policy primary factor gives in the column where 'No Policy' is written, to the amount of waste collected is shown.   Because the RDF and compost policy has been in effect since 1992, the value for the column where it is written, 'With Policy' is shown, and for the purpose of looking at the influence supposing that the policy had not been initiated, the value in the case that there is not a policy is also sought which is given in the 'No Policy' column.   In addition, for the policy elasticity, both the amount collected in the case that there is a policy and in the case that there is not a policy are included.

There is a tendency for the amount of waste collected to increase as the sale price increases.

However, the elasticity value is small and therefore there is not much of an influence on the amount of waste collected.   Also, looking at the difference in the elasticity value, which is 0.004, for with and without a policy for the sale price for the same year, it appears that there is no marked influence whether there is a policy or not for the primary factor which is the sale price.

On the other hand, the elasticity value for the policy dummy shows a much larger minus value than for the sale price elasticity value.   With this policy, where there is a separate collection system for both kitchen waste and combustible waste, due to separation it has actually been demonstrated that there is a minus effect in controlling the amount of waste that is discharged.   It has been shown that thorough separation leads to a reduction in waste.   It is thought that separation will result in an increase in the number of cases where waste that can be recycled will not flow towards the usual treatment route and be treated at households.

Table 2: Simulation Results

	Policy 1		Policy 2	
	Nogi	Haibara	Nogi	Haibara
W_1 (moisture content, %)	22.2	40.2	34.5	45.5
W_5 (moisture content, %)	4	6	4	6
W_7 (moisture content, %)	3.23	4.86	3.23	4.86
Q_1 (material flow, t)	3320	2017	4847	2347
Q_2 (material flow, t)	332	403	485	469
Q_3 (material flow, t)	2988	1614	4362	1878
Q_4 (material flow, t)	565	587	1387	790
Q_5 (material flow, t)	2423	1027	2975	1088
Q_7 (material flow, t)	2403	1014	2952	1075
Q_7/Q_1 (RDF production ratio, %)	72.4	50.3	60.9	45.8
RDF low level calorific value	4262	3814	4222	3823

4. Evaluation of the Policy Concerning the Recycling of Waste

4.1 Simulation Analysis of the Produced RDF

(1) Setting of the Model for the Simulation Analysis

Using the data of the physical composition, etc. of waste from Nogi Town, Tochigi Prefecture and Haibara Town, Nara Prefecture, a simulation analysis of RDF production will be carried out.

The physical composition of waste that is a combination of kitchen and other combustible waste for Nogi Town, Tochigi Prefecture and the physical composition for Haibara Town, Nara Prefecture that is producing RDF from combustible waste (excluding plastics) that includes kitchen waste is as given in Table 3.

Table 3: Physical Composition of Waste for Nogi Town and Haibara Town(Wet base: %)

	Paper	Plastic	Kitchen waste	Fibers	Vegetation	Non-combustible items	Total
Nogi Town	28.71	14.85	31.51	12.7	6.1	6.13	100
Haibara Town	49.25	17.83	14.05	0.36	7.75	10.76	100

Source: Nogi Town, Tochigi Prefecture Environment Traffic Section, Haibara Town,　reference 7), 8).

In this paragraph two policies will be considered as follows:

Policy 1: Producing RDF from combustibles while excluding kitchen waste.

Policy 2: Producing RDF from combustibles and kitchen waste.

Here Policy 1 is the policy that is presently being practiced in Nogi Town, Tochigi Prefecture. Policy 2 is the policy where combustible waste and kitchen waste are not separated and is what is being practiced in Haibara Town, Nara Prefecture.

With respect to each of these policies as given above, an evaluation from the standpoint of the calorific value and moisture content of RDF will be carried out.

The composition of the waste is divided into paper, plastic, kitchen waste, fibers, vegetation, and non-combustible waste.　The amount produced of each is given by X^0_k , X^0_p , X^0_c , X^0_s , X^0_m , X^0_f . If the total amount of waste produced is X^0_t , then $X^0_t = X^0_k + X^0_p + X^0_c + X^0_s + X^0_m + X^0_f$.　In addition, in order to produce RDF, the ratio of each is given by r_k , r_p , r_c , r_s , r_m , r_f　(in the case of

policy 2, $r_k = r_p = r_c = r_s = r_m = r_f = 1$),

$X_t = r_k X^0_k + r_p X^0_p + r_c X^0_c + r_s X^0_s + r_m X^0_m + r_f X^0_f$

$\quad = X_k + X_p + X_c + X_s + X_m + X_f$

The basic process for producing RDF is given below.   The material Balance will be calculated[7].
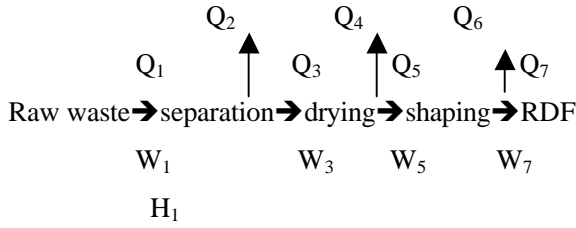
Q: Material flow, W: Moisture content, H: Low level calorific value

Figure 3: Basic Process for RDF Production

If the waste used for raw material has a low level calorific value H_1, a moisture content W_1, and a high level calorific value H_1^h they are given as follows:

$H_1 = 1/ X_t[\{ H_k(1- W_k)-600 W_k\}X_k + \{ H_p(1- W_p)-600 W_p\}X_p + \{H_c(1- W_c)-600 W_c\}X_c +\{ H_s(1- W_s)-600 W_s\} X_s + \{ H_m(1- W_m)-600 W_m\} X_m]$

$W_1 = (W_k X_k + W_p X_p + W_c X_c + W_s X_s + W_m X_m) / X_t$

$H_1^h = (H_1+600 W_1)/(1- W_1)$

In the separation process for Nogi Town, Tochigi Prefecture about 10% of the raw material waste which is non-suitable is removed.   Similarly, about 20% is removed at Haibara Town, Nara Prefecture.

$Q_2=0.1 Q_1$ (Nogi) $Q_2=0.2 Q_1$ (Haibara)

Assuming that there is no change in the moisture content before and after the separation, $W_1=W_2$. Also, since the moisture content of the non-suitable items is not considered to have a large effect on the water balance, for purposes of simplification, $W_1=W_2=W_3$.

It is necessary to reduce the moisture content in the RDF, to below 10%, in order to limit rotting

and unpleasant odors.   The actual results at Nogi Town, Tochigi Prefecture show that the moisture content after the drying process is about 4% and similarly it is about 6% at Haibara Town, Nara Prefecture.

W_5=0.04 (Nogi), W_5=0.06 (Haibara),

$Q_5 = Q_3 \{(1- W_3)/ (1- W_5)\}$

$Q_4 = Q_3 - Q_5$

In Nogi Town, Tochigi Prefecture the moisture content after the shaping process is about 3% and similarly about 4% for Haibara Town, Nara Prefecture.   In the shaping process, assuming that about 20% of the moisture remaining is evaporated, $W_7 = 0.8 Q_5 W_5 / Q_7$, $Q_7 = (1- W_5)Q_5 + 0.8 Q_5 W_5$.

In addition, the low level calorific value for RDF is given by $H_7 = H_1^h(1- W_3) - 600 W_7$.

As data for the amount of waste produced, for the year 1995, the value of 4847 tons of collected combustible waste, which includes raw waste is used for Nogi Town, Tochigi Prefecture and the value 2347 tons is used for Haibara Town, Nara Prefecture.

Data for water content, calorific value, etc. are given in Table 4.

Table 4: Data for Moisture Content and Calorific Value

	Paper	Plastic	Kitchen waste	Fiber	Vegetation
Moisture content (%) (Nogi)	24.7	18.7	61.4	21.7	41.8
Moisture content (%) (Haibara)	49.2	33.3	78.3	54.0	54.0
High level calorific value (Kcal/kg)	3900	8000	4200	4100	4000

* The dry base is used for the calorific value.

Source: The moisture content for Nogi and Haibara are taken from reference 7), and the high level calorific value is taken from reference 9).

The aforementioned expressions, data for the amount of waste produced, moisture content and calorific value, were used to carry out an analysis.   The results are given in Table 5.

(2) Comparative Study of Policy

A comparative study of Policy 1 and 2 will be carried out for Nogi Town, Tochigi Prefecture, and Haibara Town, Nara Prefecture.   For Nogi Town, Tochigi Prefecture, due to the influence of kitchen waste for Policy 2, the moisture content (W_1) in the waste is high, the amount of moisture (Q_4) that is evaporated in the drying process is 2.5 times more than that for Policy 1.   Also, it was found that the ratio of RDF produced from the raw material waste (Q_7/Q_1) was 60.9%, which was lower than that for Policy 1.   However, the amount of RDF produced (Q_7) with a large portion of kitchen waste, was more than for Policy 1.   It was also noted that there is hardly any difference in the RDF low level calorific value between the two policies.

In addition, at Haibara Town, Nara Prefecture, the moisture content (W_1) of the raw material waste, considering all constituents, was higher than for Nogi Town, Tochigi Prefecture.   The amount of moisture (Q_4) evaporated by the drying process was 1.3 times greater for Policy 2 than Policy 1. However the ratio of RDF production to raw material waste was 50.3% for Policy 1 and 45.8% by Policy 2, which was not much different from Nogi Town, Tochigi Prefecture.   Also, the low level RDF calorific value was higher for Policy 2.   Similarly, there is a large influence, particularly in the drying process since kitchen waste has a large moisture content compared with the other constituents,. However, there is not as much of a difference seen when considering other points.

The amount of kerosene used in the drying process at Nogi Town, Tochigi Prefecture was about 82 liters per ton of waste carried in[7].   Also, supposing that the cost of kerosene is 34 yen/liter, and noting that the difference in the amount of waste carried in between Policy 1 and Policy 2 is 1527 tons, conversion into a monetary value gives about 4,260,000 yen (1527t*82liters/t*34yen/liter).   From the fact that about 8,000,000 yen is spent each year on kerosene at the Nogi Town Recycling Center, by Policy 2 there would be an increase by a factor of 50%.   Even at Haibara Town, Nara Prefecture, making the same calculation results in about 960,000 yen (330t*86liters/t*34yen/liters).   If the produced RDF were used instead of kerosene in the drying process, it would be possible to economize on the kerosene fee.   In addition, there is a problem for the environment due to the combustion of this much kerosene which causes a much greater burden.

Table 5: Elasticity Value for the Simulation

	Sale Price Elasticity		Policy Elasticity			
	With Policy	Without Policy	With Policy	Amount Collected (g/person day)	Without Policy	Amount Collected (g/person day)
1986	-	0.00955	-	-	0	433
1987	-	0.00959	-	-	0	472
1988	-	0.00961	-	-	0	498
1989	-	0.00964	-	-	0	542
1990	-	0.00966	-	-	0	575
1991	-	0.00967	-	-	0	599
1992	0.00502	0.00969	-0.13241	552 (13.2%)	0	637
1993	0.00518	0.00971	-0.15827	571 (15.8%)	0	678
1994	0.00535	0.00973	-0.18380	592 (18.3%)	0	726
1995	0.00548	0.00974	-0.20145	609 (20.1%)	0	762

*The value in the brackets '（　）' is that the percentage the amount is reduced.

The local residents of Nogi Town, Tochigi Prefecture have RDF and compost made out of their garbage that they themselves dispose of.　With respect to the compost it is returned back to them, so in order to produce a better compost there is an incentive to make the effort to properly separate their garbage thus shaping a recycling society.　It would be no exaggeration to say that the quality of both RDF, as well as compost is determined by how the waste is separated.　Considering RDF, if the separation rate is increased, the calorific value also is increased resulting in a better quality solidified fuel.

In terms of separation, remarkable progress has been made with respect to the precision of the RDF equipment and its durability, in comparison to the first ones of their kind.　However, as the cooperation of residents is indispensable in separating waste, the incentive mentioned previously for Nogi Town, Tochigi Prefecture produces good results.　It is thought that this is the reason why Nogi Town, Tochigi Prefecture was chosen as the Ministry of Health and Welfare model self governing body (Clean Recycle Town) for 1994.

From the above discussion, it is thought that Policy 1 is superior.　However, if there is no demand for both RDF and compost, a system can not be realized.　In Nogi Town, Tochigi Prefecture, as there

are many farm households, there is a demand for compost. However, since there is only a small number of farm village areas in the city region, the demand for compost is also low. Making compost from the city garbage and shipping it to the agriculture area has been thought of but the cost is too high.

Therefore, it is thought that this policy can only be implemented in the agricultural region for Nogi Town, Tochigi Prefecture. In addition, with respect to RDF, it is necessary to find a market for demand such as the one in Sapporo City where it is used in combination with fossil fuels in an area heating-cooling system.   It is thought that if this can be found, then it would be possible to implement Policy 2, even in a city area.

As given above, in the case that an RDF production policy is implemented, upon a comprehensive examination, it will be necessary to determine the policy, only after the quality and state of the waste handled by each self governing body and the development of industry is ascertained, while looking at the cost, environment and energy expenditure side over the long period.

4.2 Evaluation Analysis of the Influence of Plastics

(1) Evaluation Analysis of the Influence of PET Bottles

An analysis of the influence of PET bottles will be carried out using the data from the previous section. With respect to PET bottles, they must be separately collected and recycled as of April 1, 1997, according to the law concerned with the promotion of separated collection and recomercialization for containers and packaging (1995 Law No. 112) (Commonly known as the "Container and Packaging Law").

Now an analysis of the effect of removing pet bottles from the other combustible waste in Nogi Town, Tochigi Prefecture will be carried out.   In Nogi Town, Tochigi Prefecture, separated collection of pet bottles has been carried out since October 1, 1996 after which they are transported to the PET Bottle Recycle Center located in Minamikawachi Town, Tochigi Prefecture.

The expression for calculation of the calorific value, moisture content and the associated data used here is the same as is given in the previous section.   In addition, since there is no data for the amount of PET bottles in Nogi Town, an estimate will be made based on data from Kounosu City, Saitama Prefecture[10].   It is assumed that the amount of pet bottles collected increases in proportion to the population.

Table 6: Population and the Amount of PET Bottle Collected for Kounosu City

	1992	1993
Population	76,885	78,604
Amount of PET Bottles Collected (kg)	35,145	35,335
Amount Collected per person (kg/person)	0.457	0.450

Taking the average of 1992 and 1993, the amount collected per person is 0.4535 kg. As the population for 1995 of Nogi Town was 26,491, this gives a PET bottle collection amount of 12.01 tons. The results of the analysis are presented in table 7. The left column, denoted 'Policy 1', is the present policy and the right column represents the policy involving the removal of PET bottles, which is denoted 'Removal of PET Bottles'.

By comparing the present policy and the policy where PET bottles are removed, it can been seen that there is a slight decrease in the amount produced (Q_7), in the case that PET bottles are removed. However, the moisture content in the RDF (W_7), production ratio (Q_7/Q_1), and the low level calorific value equally display only a small difference showing that there is not much of an influence whether PET bottles are removed or not. It is therefore thought that it is necessary for PET bottles to be recycled by material recycling (material collection) rather than by thermal recycling (heat recycling).

Table 7: Results of Simulation

	Policy 1	Removal of PET Bottles
W_1 (moisture content, %)	22.2	22.2
W_5 (moisture content, %)	4	4
W_7 (moisture content, %)	3.23	3.23
Q_1 (material flow, t)	3320	3308
Q_2 (material flow, t)	332	331
Q_3 (material flow, t)	2988	2977
Q_4 (material flow, t)	565	563
Q_5 (material flow, t)	2423	2414
Q_7 (material flow, t)	2403	2394
Q_7/Q_1 (RDF production ratio, %)	72.4	72.4
RDF low level calorific value (kcal/kg)	4262	4248

(2) Evaluaition Analysis of the Influence of Other Plastics

An analysis was carried out on the relationship on the RDF low level calorific value in the case that after pet bottles were removed, as given in part (1), only the amount of other plastics contained in the RDF was varied for Nogi Town, Tochigi Prefecture. For comparative contrast, the same was done where only the amount of paper contained in the RDF for Nogi Town, Tochigi Prefecture was varied. The results are shown in figure 4.

Looking at this, it can be seen that the calorific value is high when the content of plastic is high, while paper shows the opposite trend. This is due to the fact that paper has a high moisture content which is thought to have the effect of lowering the high level calorific value. For plastics, depending on the percentage contained, there is at most, a difference of 1000 kcal/kg, while the difference of varying the paper percentage amounts to only 300 kcal/kg at most. It was therefore found that plastics have a large influence on the calorific value of RDF.

In order for the plastic recycling policy to succeed, the following three things will be necessary[12]:
① That a moderate infrastructure be prepared for the purpose of collecting plastics.
② That it is possible to use technology in order to make recycled items economically from plastics.
③ That a market be established so that the recycled items are used effectively.

From April 1, 2000, separate collection of plastics besides PET bottles will also have to be carried

out according to the Container and Packaging Recycling Law. Recycling is being sought, but upon paying attention to the above point, it is felt that the production of RDF using plastics should also be thought of as one method for plastic recycling.
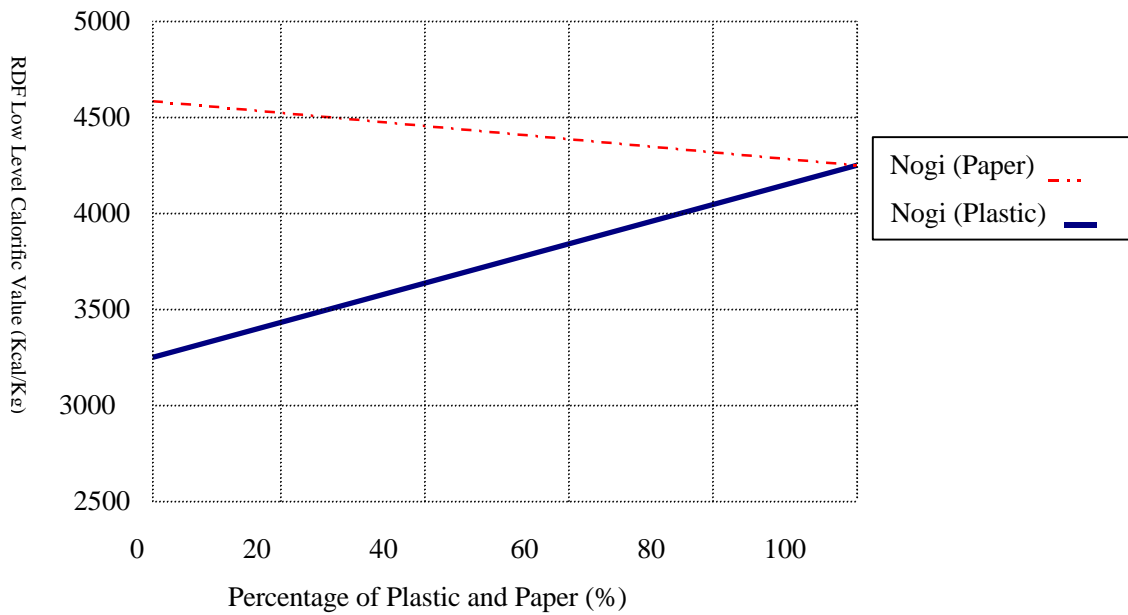
Figure 4: Relationship Between the Ratio of Plastic and Paper and the Calorific Value

5. Conclusion

The results obtained in this research are as follows:

(1) Upon analysis of the effect of a reduction in waste for Nogi Town, Tochigi Prefecture, not by the policy of producing RDF and compost, but by the simultaneous implementation of a combustible waste and raw waste separate collection system, a minus effect of controlling the amount of waste that is disposed of was demonstrated.

(2) Using the physical composition of waste from Nogi Town, Tochigi Prefecture and Haibara Town, Nara Prefecture, the results of the RDF production simulation analysis that was carried out, it was found that there is a large amount of moisture evaporated in the drying process due to the influence of moisture content of kitchen waste, which lowers the amount of RDF that can be made.   However the RDF low level calorific value in the case of comparing the amount of RDF produced from waste that includes and does not include kitchen waste shows almost no difference at all.

(3) In relation to the ' Container and Packaging Recycling Law' , the results of the analysis of the influence on RDF production, in the case that PET bottles are removed from waste in Nogi Town, Tochigi Prefecture, with respect to the amount produced, the moisture content of RDF, the ratio of RDF produced from waste and the low level calorific value, show that there is hardly any difference.

It is therefore necessary to recycle PET bottles by using the method of material recycling (material collection).

(4) The result of the analysis of the influence on RDF of plastics except for PET bottles showed a difference of 1000 kcal/kg.   Therefore, for RDF production it was seen that plastics are indispensable.

Footnotes

1) rate of recycling= amount recycled with intermediate treatment/treatment of total amount handled

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