COST SIMULATION STUDY FOR THE BIOMASS CO-COMBUSTION SYSTEM IN LARGE SCALE POWER PLANT

A. NISHIYAMA[1], Y. HARIGANE[2], S. KAMBARA[2], and H. MORITOMI[2]
[1]C-Tech Corporation, Ltd., [2]Gifu University
a.nishiyama@ctechcorp.co.jp

ABSTRACT

To reduce CO_2 emission and establish sustainable social system, biomass energy is being watched as renewable energy and carbon-neutral fuel. The scale of biomass power plants is generally smaller than conventional thermal power plants because of the limitation of the amount of biomass fuel to be supplied. However, in construction of small biomass power plants, both initial and operation costs are higher than the large scale plants, and thermal efficiency is not so high.

The objective of this research is to establish the cost simulation methods for biomass firing processes that have minimum cost and high efficiency by co-combustion with coal in large scaled conventional boilers. To reduce the initial construction cost, co-combustion by the conventional coal fired boilers is available. The most important factor is the reduction of supplying costs for the biomass fuel. Biomass source is normally in mountain, but a consumer is in near sea. Therefore, the transportation costs occupy almost all of the total cost.

With regard to the process simulator for power plant, chemical plant and others, "Aspen Plus" and "ECLIPS" are the most popular, and many studies based on these simulator has been performed and reported. On the other hand, we are developing a new simulator to evaluate the following performances of the biomass co-combustion process in large scaled power plant.

- Biomass collection and transportation cost calculation forest to power plant
- Critical issue on pre-treatment and pulverizing system for biomass fuel
- Initial and operation costs calculation considering the value added environmental issue

To study the possibility of the co-combustion process in technically, economically and realistically, As an example, Aichi prefecture region is selected in this study. And the evaluation is done based on 700MW utility power plant, and the mixing ratio of biomass is varied between 0 - $20\%_{th}$ in this paper.

KEY WORDS: 1. biomass 2. power plant 3. cost simulation 4. co-combustion.

1. INTRODUCTION

Kyoto Protocol was issued on January in 2005, and the use of renewable energy and new energy for the reduction of CO2 are realized in Japan. In these situations, biomass applications are expected as a major player. The use of woody biomass is exactly important theme in Japan, because Japan has been a prominent forest established country, and Japan has a history of forest resources use as a primary energy and other resources in our life from a long time ago. Terrestrial environmental problem is new. However, to break away from the fossil fuel and to return to forest and woody biomass of renewable energy resources is basic theme for us, and also familiar and real theme. And it is not other than to construct the continuous possible Japan.

In Japan, many kinds of new technology to utilize the woody biomass are continued to develop supported by national government and others. From a view point of energy supply, since heat supply infrastructure is quite defective in Japan, a electricity power supply is selected as a primary use, instead of heat supply. Therefore, most of woody biomass plants are normally small size CHP with several hundreds kW generator. However, it is said generally, the CHP electric power efficiency is quite low, and both unit of construction cost and unit of operation cost are not avoided to increase. On the other hand, a larger scale plant is difficult to construct because of the limitation of heat supply capability in Japan as above mention. It must be Japanese weak point in the biomass utilization.

In order to solve this dilemma, we would propose woody biomass co-combustion with coal in conventional large scaled power plant. To apply co-combustion with fossil fuel, plant owner can be released from the risk of stable collection of large amount of biomass. And if conventional boiler can be applied, initial const can be reduced drastically, and also the cost of plant operator may be not increased. And anyhow, the high performance of conventional power plant is expected to take over to biomass co-combustion process.

Several power companies and industrial companies in Japan have already carried out the development using their own coal firing power plants in Japan. And the biomass mixing up to 2-3% of total heat input has been already demonstrating and established technically This paper evaluates on the technical and economical issues to archive the larger mixing ratio of biomass based on the results of process and cost simulation study.

2. DEVELOPMENT OF BIOMASS CO-COMBUSTION SIMULATOR

2.1 GENERAL

In many demonstration project, the mixing ratio of biomass is normally very small. One of the main reasons is coming from balance of biomass amount and collection cost. Therefore, the economical issues are important rather than some technical issues. We firstly maid the process simulator combined some conventional simulation models for coal fired boiler process, and then added the cost simulation model on the forest wood collection and transportation works based on the published papers. Calculation procedure is shown in Figure 1.

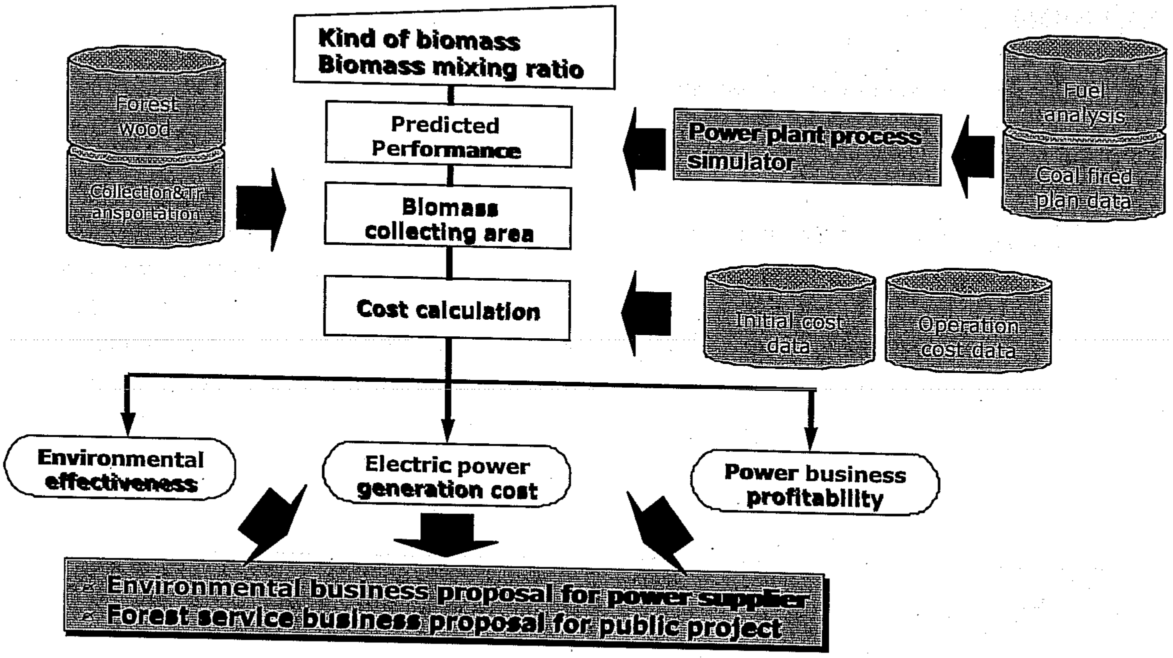


Figure 2: Calculation procedure of Developed Process Simulator

2.2 MODELING FOR BIOMASS COLLECTION AND TRANSPORTATION

2.2.1 BIOMASS CLASSIFICATION

In this process, cost for biomass collection and transportation is quite important function, because larger amount of biomass should be collected and transported from wider area with higher cost. Therefore, the price of biomass has a strong correlation with the possibility of biomass collection. In this model, three different type of woody biomass as shown in Table 1 is considered.

Table 1: Woody biomass classification used for this study

Code	Type	Condition
1	Wood industry waste	This is transported from wood industry from the average distance of 30 km in neighbouring area. Average moisture content is 20%.
2	Fuels from thinning	This is transported from the northern parts of Aichi prefecture with the distance of 100 km. Average moisture content is 50%.
3	Forest soil remainder	This is assumed the same condition as Fuels from thinning of Code 2.

2.2.2 BIOMASS COLLECTION AND TRANSPORTATION

The cost evaluation is considered as purchase price of fuels from thinning itself, cumbering and track loading price and transportation price to power plant. These prices are defined as Table 2, based on the R&D paper1) published by Forest Agency.

These costs and prices are much different, depending on the region, the season, the working machine and other conditions, and those are not so easy. In this study, all of purchase prices are assumed zero (0). And the price for cumbering, track loading price and transportation are used typical and average one. The distance L in Table 2 is used an average transporting distance from mountain area to power plant entrance. And transportation is assumed loading of 8 m^3 per one track with the track of 4 tons type.

Table 2: Collecting and transportation price definition

Code	Name	Condition
1	Wood industry waste 1) Purchase price (JPY/wet-ton): 2) Cumbering (JPY/wet-ton): Track loading & transportation price (JPY/wet-ton) :	 = Zero (0) = Zero (0) = 23.5 × L (km) + 1701.8
2	Fuels from thinning 1) Purchase price (JPY/wet-ton): 2) Cumbering (JPY/wet-ton): - Loose inclined plane (less than 15 °) - Middle inclined plane (larger than 15–25 °) - Steep inclined plane (larger than 25 °) Track loading & transportation price (JPY/wet-ton) :	 = Zero (0) = 6,000 = 8,000 = 11,000 = 23.5 × L (km) + 1701.8
3	Forest soil remainder 1) Purchase price (JPY/wet-ton): 2) Cumbering (JPY/wet-ton): Track loading & transportation price (JPY/wet-ton) :	 = Zero (0) = Zero (0) = 286.26 × L (km) + 1300.4

2.3 MODELING FOR COAL FIRED POWER PLANT

2.3.1 POWER PLANT FUEL CONDITIONS

Fuel analysis for biomass and coal for the study is shown in Table 3. Two cases of biomass fuel for power plant are assumed. Biomass (A) is a case of 100% wood industry waste. Biomass (B) is combination case, and the mixing ratio of "Wood industry waste", "Fuels from thinning" and "Forest soil remainder" is constant of 20:30:50 as weight percent. The difference between Biomass (A) and Biomass (B) is only moisture content.

Three types of coal fuel is studied. Coal (A) is selected as a standard coal and design basis, and coal (B) with low Hard Grove Index (H.G.I.) is selected to discuss on the mill system performance, and then coal (C) with high moisture content is used for the study on the flue gas treatment system.

Table 3: Fuel analysis used for this study

Item	Unit	Base	Biomass (A) Waste origine	Biomass (B) Forest origine	Coal (A) Standard	Coal (B) Low H.G.I.	Coal (C) High moisture
Gross heating value	MJ/kg	Dry	18.84	18.84	30.27	28.47	27.59
	kcal/kg	Dry	5,000	5,000	7,423	7,188	7,347
Moisture	Wt.%	As received	20.00	50.00	9.40	11.30	14.7
Ash	Wt.%	Dry	0.6	0.6	11.9	9.2	4.7
Volatile matter	Wt.%	Dry	88.9	88.9	26.5	45.8	45.4
Fixed Carbon	Wt.%	Dry	10.6	10.6	61.6	45.0	49.9
N	Wt.%	Dry	1.11	1.11	1.89	1.25	1.64
S	Wt.%	Dry	0.01	0.01	0.52	0.66	0.66
Cl	Wt.%	Dry	0.01	0.01	0.03	0.02	0.01
H.G.I.	-	Air dry	-	-	75	36	50

2.3.2 PROCESS CONSIDERATIONS

General process flow of coal fired power plant shown in Figure 3. Biomass process should be considered depending on the receiving size, moisture content, target mixing ratio and other conditions. Biomass co-combustion process is typically assumed five different process, and the concept of each process is explained in Table 3.

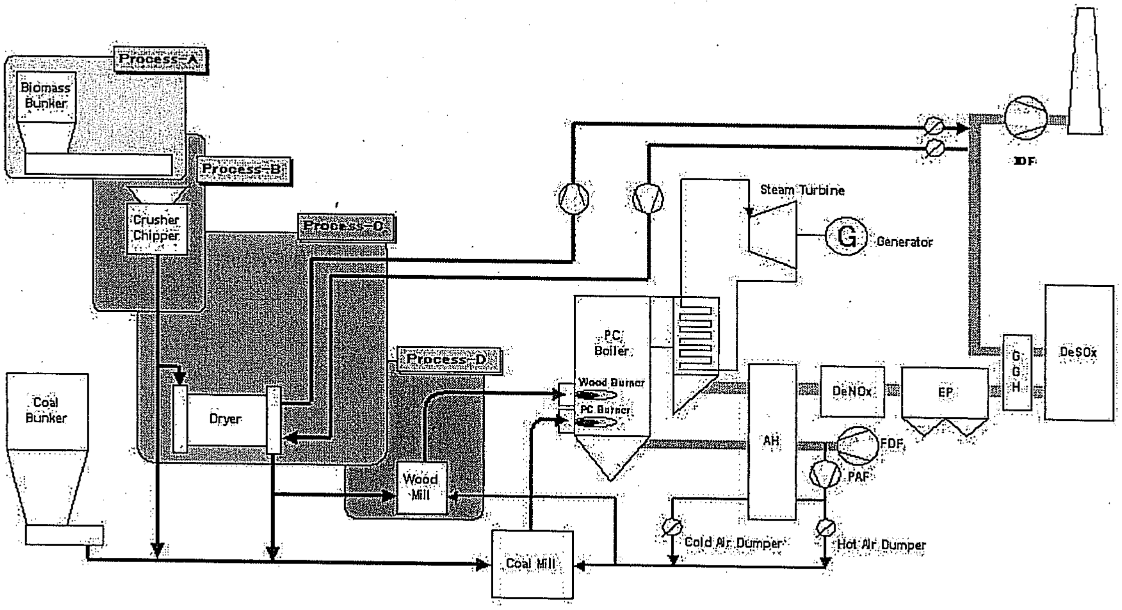


Figure 3: General flow sheet of coal fired power plant used for this study

Table 4: Biomass co-combustion process cases

Process	Object	Power plant system requirement
A	Most simplified system with cheapest biomass use with Biomass (A)	Existing system with biomass receiving, storage and continuous and quantitative feed system
B	Use of non-fixed form biomass with Biomass (B)	Process A with biomass chipping system
C-1	Use of high moisture content biomass with Biomass (B)	Process B with biomass drying system before transportation
C-2		Process B with biomass drying system in power plant site
D	Application for wider range of biomass mixing ratio with Biomass (B)	Process C-2 with biomass mill system for exclusive use

2.3.2 BOILER AND AUXILIARY EQUIPMENTS

The performance, heat and material balance, and utility consumptions including electric power, industrial water and various chemicals, for boiler itself and auxiliary equipments are calculated by published method and equations, which are shown in Table 5. Another calculations for miscellaneous equipments are also performed using general specification, information and others in order to evaluate total power plant

Table 5: Details for simulation modelling

System	Included calculation items in model
Mill system	1) HGI correction with woody biomass mixing2)
Combustion chamber	1) NOx and unburned carbon prediction3) 2) Furnace gas temperature distribution prediction4)
Furnace and boiler tubes	1) Slugging risk calculation for the limit of mixing ratio 2) 2) Fouling risk calculation for the limit of mixing ratio 2)
Environmental Equipments	1) DeNOx performance and NH_3 consumption2) 2) DeSOx performance and $CaCO_3$ consumption2) 3) ESP performance and power consumption2)

2.4 ECONOIMICAL EVALUATIONS

2.4.1 COST CALCULATION FOR ELECTRIC POWER GENERATION

This simulation study is applied Aichi prefecture in this report. Biomass fuel is collected from the forest of northern east area of Aichi prefecture, and assumed to be supplied to 700MW utility power plant in seaside of Aichi. This study is performed based on 700MW utility power plant. In this case, the average distance of transportation is estimated 30 km for Biomass (A), and 100km for Biomass

(B). Based on this common condition, plant performance calculation with various biomass kinds and process cases are estimated. Plant operating condition is normal utility plant basis as follows.

- Annual operating : 8000 hours basis
- Start-up and shut-down operation : once per year
- Load condition : 100% constant, base load operation basis

Total fuel consumption, total power consumption and utility consumption are calculated, and furthermore the calculation for economical evaluation is based on the conventional procedure with general conditions.

2.4.2 EVALUATION ON EMVIRONMENTAL EFFECT

Since the retail enterprise of electricity possesses obligation to use the renewable energy based on the Renewable Portfolio Standards (RPS) Rule, which was enforced in 2003. Biomass energy has advantage of economic value for electric company. This value is called RPS credit in below. RPS credit is bought in various prices of upper limit of 11JPY/kWh. In this study, several cases for RPS credit are assumed and evaluated.

Biomass energy use is also expected the paragraph tax effect depending on the new tax called "Environment Tax" or "Carbon Tax". At this moment, this tax is under consideration in national government and another organizations. Economical effect on this and CO2 reduction cost using this biomass process are also evaluated.

3. RESULTS AND COSIDERATION

3.1 CONDITIONS FOR STUDY

As shown Table 6, the eight (8) different cases are selected for this study. And the cases from Case-I to Case-V are used for the study on the basic characteristics of each process. And Case-VI and Case-VII is to evaluate on the possibility for the wider range of coal application. And finally, case-VIII is selected as most difficult fuel case in technically and economically. All of the results of performance and economical calculation show relative values. These are plotted the difference from the value of Case-I with coal 100 % case.

Table 6: Calculation cases

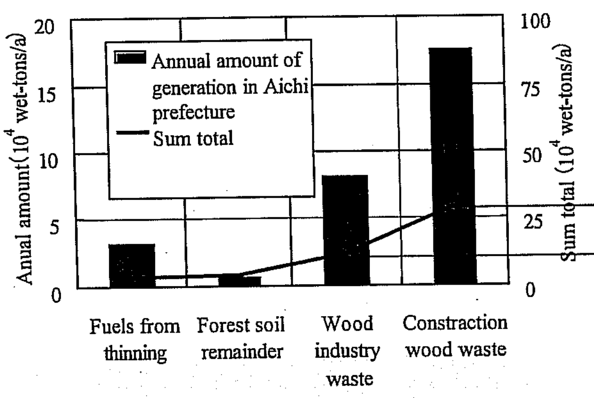
CASE	Process	Coal	Biomass
CASE-I	A	(A)	(A)
CASE-II	B	(A)	(B)
CASE-III	C1	(A)	(B)
CASE-IV	C2	(A)	(B)
CASE-V	D	(A)	(B)
CASE-VI	C2	(B)	(B)
CASE-VII	C2	(C)	(B)
CASE-VIII	D	(C)	(B)

3.2 POSSIBLE AMOUNT OF BIOMASS CO-COMBUSTION

Figure 4 shows the total amount of biomass generation in all of Aichi prefecture. This is shown various kinds of biomass, including construction wood waste, which is expected as a big energy resource. In case of without construction waste, biomass of 120,000 tons/a is possible to apply. If construction wood waste is added, it can be increased to 300,000 tons/a. And if the stream of forest activation will be accelerated, more much amount of biomass resources are expected in this area.

On the other hand, figure 5 shows annual amount of biomass burning rate in 700MW in various mixing ratio. Burning rate of CASE-I and CASE-III is relative smaller than the others. This is caused by biomass moisture content. That is, CASE-I is used low moisture biomass and CASE-III is used dried biomass, and then the burning rate is resulted smaller values as wet basis. According to the data of Figure 4, in case of without construction waste wood, the biomass mixing ratio is 2% – 3% of total heat input of power plant as indicated by red allow. Even if construction waste wood is included, the biomass mixing ratio is 6% – 9% at largest as blue allow indicates.

In case of 700 MW power plant application, it's enough capacity to burn biomass in Aichi prefecture and much more amount of forest biomass is usable. For the advantage of this process on biomass utilization, the technical development and cost reduction for the forest wood collection and transportation are strongly requested. In this study, biomass mixing ratio is evaluated up to 20% for the future discussion,.



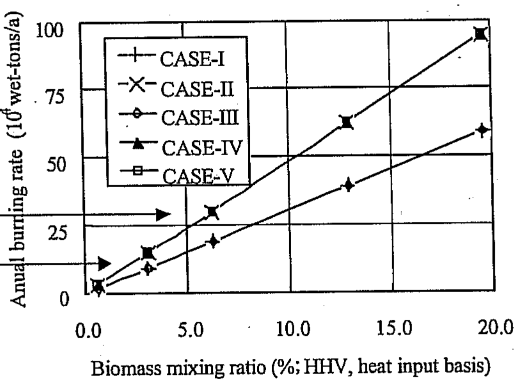


Figure 4: Amount of biomass generation

Figure 5: Amount of biomass burning

3.3 POWER PLANT PERFORMANCE

Figure 6 shows the simulation result on the gross power plant efficiency, which is calculated by power output and total thermal input of boiler, and this is plotted as the difference value with the CASE-I with coal 100%.

Gross power efficiency basically decreases in larger mixing ratio of biomass, this should be depending on the fuel moisture content. When CASE-IV, -VI and -VII with the same

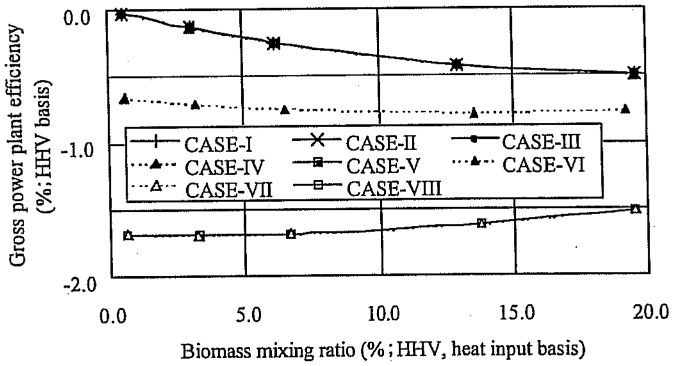


Figure 6: Power plant efficiency of gross basis

Process-C2 are compared, it can be seen the coal moisture content also has big impact on the gross power plant efficiency. That is, higher moisture content is larger boiler losses by both larger latent heat loss with evaporation and larger flue gas loss. On the other hand, moisture content of biomass is assumed 20% at boiler inlet with drying system. Therefore, the difference from CASE-I to CAST-V cannot be seen. The efficiency going up of CASE-VII and VIII of in larger mixing ratio is estimated the effect of lower unburned carbon heat loss of biomass.

Figure 7 shows net plan power efficiency. Here, net power plant efficiency is calculated as gross plant power efficiency minus internal electric power consumption. In this result, the difference from CASE-I to CASE-V can be found. The reason of this is that of the internal electric power consumption depending on the motor power for auxiliary equipments in each process. Process-I with the most simplified process results the highest efficiency.

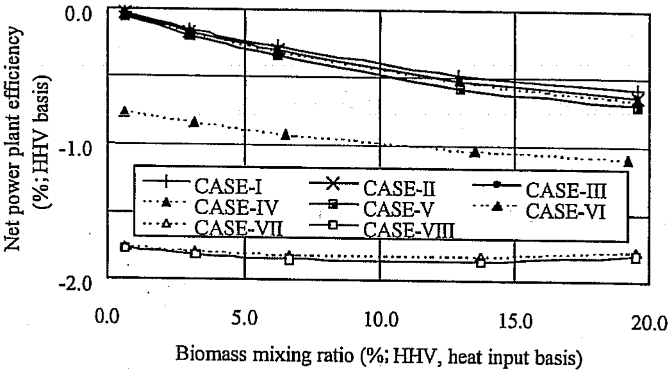


Figure 7: Power plant efficiency of net basis

The increase of internal electric power consumption in each case shows Figure 8. As mentioned above, the increase of power consumption of CASE-I is actually the smallest. The power consumption increases of CASE-VII and –VIII indicate very largest value. This is caused by larger moisture in flue gas.
As a result of this, the increase of net power plant efficiency cannot be seen in Figure 7, even though gross power efficiency is increasing in Figure 6.

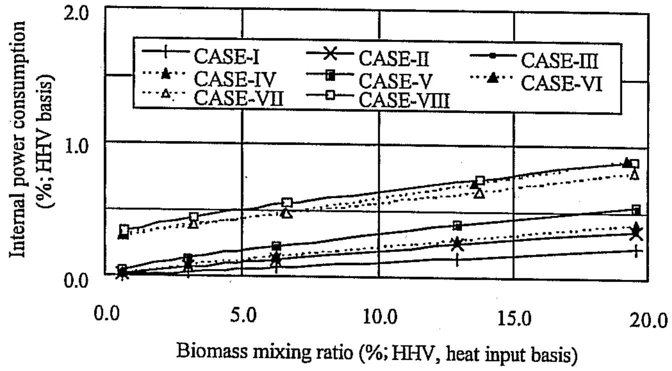


Figure 8: Internal electric power consumption

As a conclusion on the power plant performance, the larger ratio of biomass co-combustion ratio results to decrease power plant efficiency, because of higher moisture content in biomass and larger power consumption of auxiliary equipments. However, many advantages of biomass are expected as follows. These items should be evaluated not only from technical point of view, but also economical points of view. These are discussed in the following pages.

- lower environment cost for NOx and SO_2 reduction
- lower ash treatment and disposal cost
- lower fuel price (is expected)
- achieve RPS target for a electric retail enterprise
- saving environmental tax cost (in future)
- obtaining CO_2 discharge right (in future)

3.4 THE LIMITATION OF BIOMASS MIXING RATIO DEPENDING ON THE CAPABILITY OF EXISTING BOILER DESIGN

At first, the ash trouble risk of boiler itself at biomass co-combustion up to 20% was checked in the early stage, because of high alkali content in biomass ash. However, the calculation results on the slugging risk, corrosion risk and erosion risk are all "LOW" rank. The reason is estimated that the ash content of wood biomass is much lower than coal as shown in Table 3. Therefore, further consideration on this is excluded in this report.

As mention above, the increase of flue gas flow in biomass co-combustion is important issue on the existing power plant operation. The motor performance for typical equipment is checked. The motor power for induced draft fan (IDF) and boost up fan for DeSOx system (BUF) are increasing in proportion to flue gas flow increase. This is shown in Figure 9 and Figure 10. When biomass mixing ratio increases up to 20%, motor power for IDF increases 15%, and that of BUF increases 8% based on boiler design base. But the limitation of biomass mixing ratio cannot say only by this result, because this is depending on the margin of fan itself, motor, electric supply system and another existing equipments.

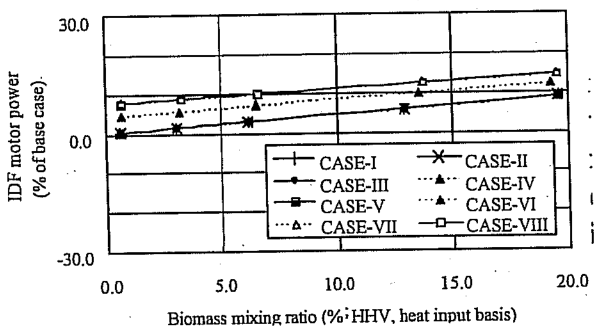


Figure 9 Increase of IDF motor power

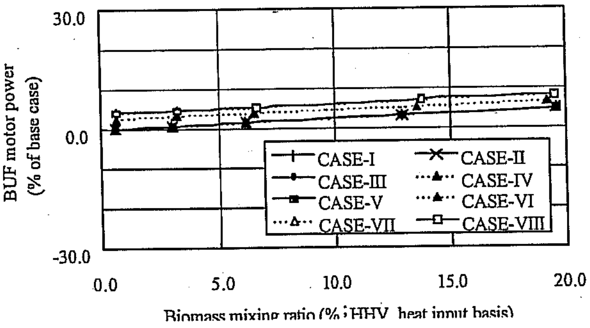


Figure 10 Increase of BUF motor power

Figure 11 shows the mill motor power increase. Larger ratio of biomass mixing requires larger power, and it is quite larger power requirement in higher moisture biomass. CASE-VI, -VII and -VIII with lower H.G.I and higher moisture coal is predicted that those are quite limited or almost impossible to burn biomass. This should be considered as the most critical issue in biomass co-combustion process. Therefore, demonstration tests for this are carried out in many projects. And we still continue the mill system model improvement for the future consideration.

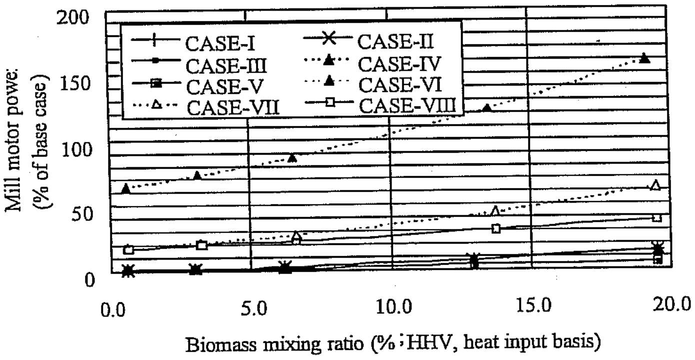


Figure11 Predicted mill motor power

Furthermore, mill system has a inlet air temperature control system as shown in Figure 3. Mill inlet air called "primary air" is controlled the temperature of mill outlet, in order to maintain the transportation performance and to avoid the ignition or explosion of coal in mill system. As shown in Figure 3, air temperature is controlled by air flow balance between "hot air" with preheated and "cold air" without preheated. Normally, higher temperature of primary air is required in case of higher moisture fuel.

Figure 12 and Figure 13 is shown the air flow control damper characteristics for both air. In case of CASE-I, both control dampers are kept at optimum opening of 50%, because this is the design point for equipments. In CASE-VII used high moisture coal, both dumper openings are critical position, even if 100% coal operation. Therefore, biomass co-combustion operation in CASE-VII is actually impossible in any mixing ratio. If Process-D is applied in case of high moisture coal, the dumper operation of both is extremely improved as the curve of CASE-VIII shows.

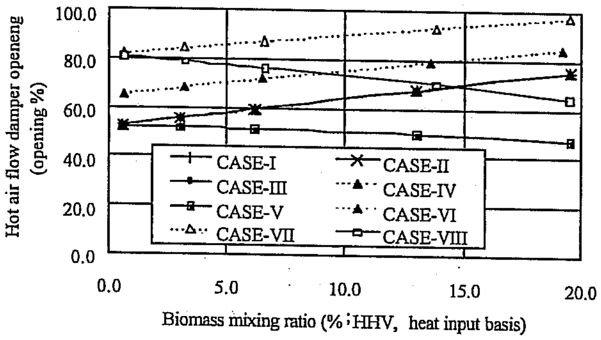


Figure 12 Hot air damper performance

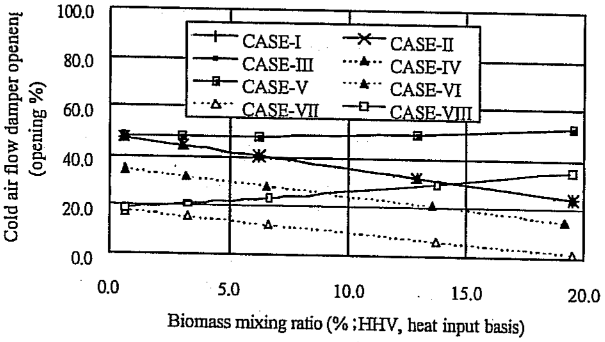


Figure 13 Cold air damper performance

The typical critical functions on the boiler performance for biomass co-combustion process are considered as above. Another functions are also possible in detail. Above simulation results are enough applicable for the detailed analysis of this process. With these results, the evaluations for economic and environment items are continued in next section.

3.5 ECONOMICAL EVALUATION

Figure 14 shows the electric power generation calculated. Because of low biomass price of waste wood and simplified co-combustion system, the cost of CASE-I does not increase. In another cases, electric power cost is increasing.

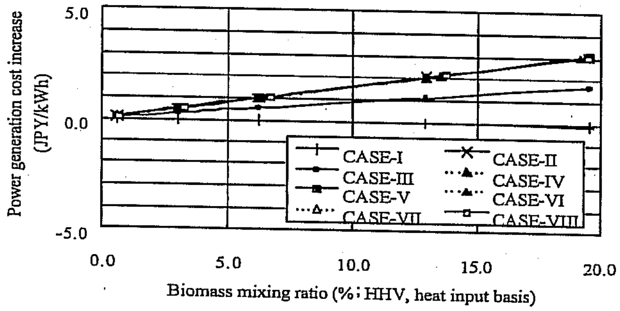


Figure 14 Electric power generation cost

Figure 15 shows the biomass fuel cost which power plant owner can pay without electric power cost increase. As a result of this, the expense for the biomass results "minus" value. That means the power selling profit cannot recover the biomass collecting and transportation cost from only economical point of view, if excluding CASE-I and CASE-III.

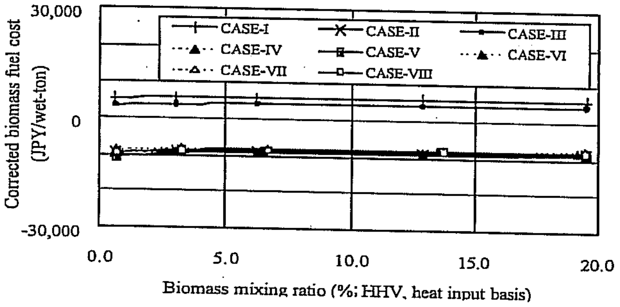


Figure 15 Required biomass fuel price

On the other, electric power sellers must introduce renewable energy of 1.35% of its total power generation by the year of2010 based on the RPS rule. RPS credit price is decided depending on the dealing condition of electricity. The effect of RPS credit for the biomass payment is shown in Figure 16 and Figure 17. Figure 16 is shown in case of RPS credit of 4JPY/kWh, and Figure 15 is in case of 6JPY/kWh. As shown in these figure, RPS credit of 4 JPY/kWh or 6 JPY/kWh is quite effective to increase the payment for forest biomass. In case of RPS credit of 6JPY/kWh, payable biomass price change to "plus" in all process cases. CASE-I and CASE-III are especially applicable, and the payments for biomass are expected 10,000JPY/ton. For another case of process, the cost reduction for biomass collection and transportation is needed.

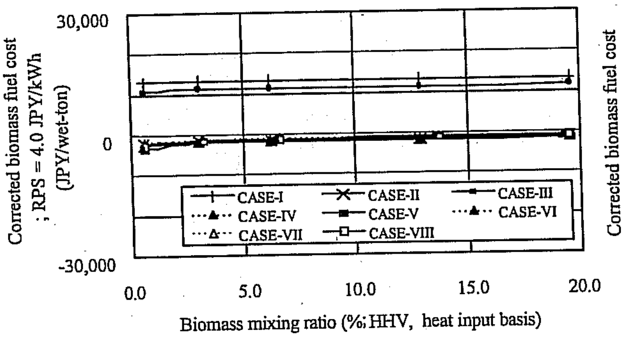


Figure 16 Effect of RPS credit of 4JPY/kW

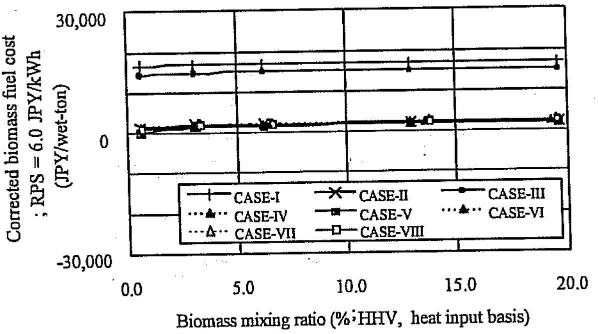


Figure 17 Effect of RPS crditi of 6JPY/kWh

3.6 EMVIRONMENTAL EVALUATION

In generally, a sufficient profitable business with biomass fuel is not easy in Japan, as mentioned above. Figure 18 shows total amount of CO_2 reduction in coal fired power plant by the application of this process. Because of large scaled power plant, the effect of CO_2 reduction is expected quite large even if the mixing ration is just small. This is corrected CO2 generated by the fuel for biomass collection and transportation.

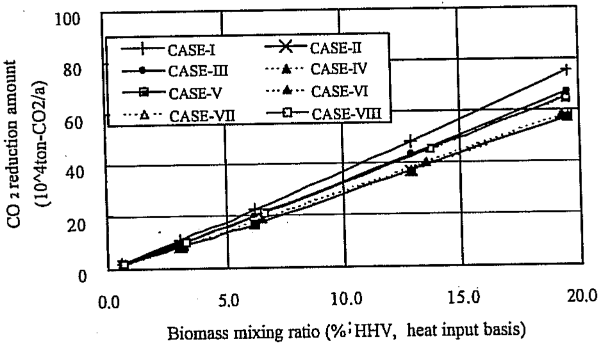


Figure 18 Amount of CO_2 reduction

Figure 19 shows CO_2 reduction cost calculated as Eq. (1).

$$\begin{aligned}&CO_2 \text{ reduction cost (JPY/ton-}CO_2\text{)}\\&= \text{Increase of power generation cost (JPY/kWh) x Annual power generation (kWh/a)}\\&\quad / \text{ Annual amount of } CO_2 \text{ reduction (ton-}CO_2\text{/a)} \qquad \cdots \quad (1)\end{aligned}$$

The CO_2 reduction cost is quite different depending on the process case. Process-A is excellent, because of the most simple system and low fuel cost. Process-C1 is the next lowest cost. Figure 20 shows the result with RPS credit of 6.0 JPY/kWh. Comparing between Figure 19 and Figure 20, RPS credit of 6JPY/kWh has an effect the cost reduction of about 10,000 JPY/ton. As announcement of Ministry of Environment, the environment tax of 2,400 or 3200 JPY/ton-CO_2 is said. On the other hand, CO_2 discharge right is now transacted by 10 USD/ ton-CO_2 or around. Totally, 3,500 – 4,000 JPY/ton-CO_2 is expected to recover the CO_2 reduction cost. If all of these environmental values are included, the CO_2 reduction cost cannot be recovered excluding CASE-I and CASE-III.

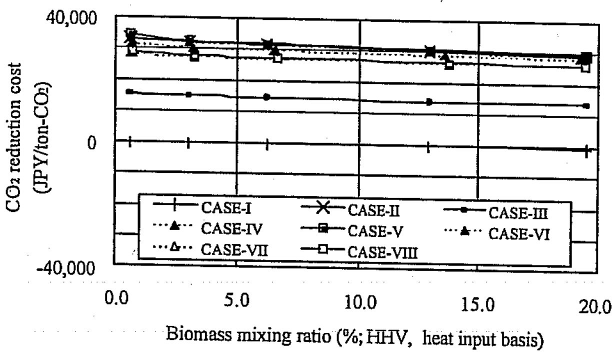


Figure 19 CO_2 reduction cost

As a conclusion for the economical and environmental evaluations, the condition of sufficient profitable business with forest biomass is very limited in the Japanese system. Simplified system use and drying in-forest system are very applicable. And RPS credit system has quite effectiveness, but it is only for electric power seller and credit is also not enough to accelerate the new biomass energy business. A new values for biomass energy, especially for forest resources, are strongly requested to be created, and much more consideration for this is necessary in near future before the fire of will be lost. We believe that this developed simulator is useful for this study as a technical and economical simulation tool.

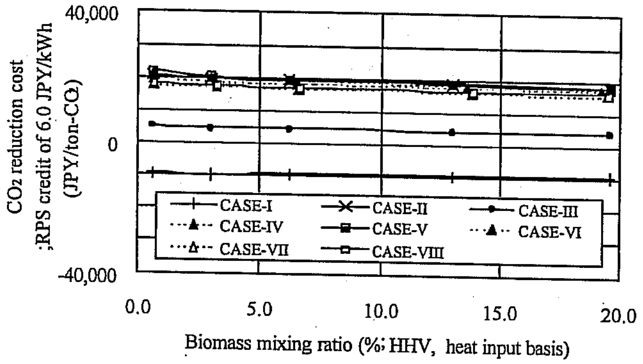


Figure 20 CO_2 reduction cost (RPS:6JPY/kWh)

4. CONCLUSION

The results of cost simulation study for the biomass co-combustion presses in $700MW_{el}$ utility power plant is concluded as follows.

1) From the limitation of biomass amount generated in Aichi prefecture, in case of forest wood biomass allowable biomass mixing ratio is 2-3%, and if construction waste biomass is added, the mixing ratio can be increase up to 6-9%.
2) The change of gross power efficiency is quite small in biomass co-combustion, but net power efficiency is clearly decreasing, because internal electric power consumption is increasing.
3) The risk of biomass mixing depending on the boiler performance is evaluated low, but risk of mill system is predicted quite big. In case of high moisture coal and low HGI coal mixing, the biomass mixing operation is actually not possible in any mixing ratio.
4) Electric power generation cost of co-combustion process is higher than 100% coal combustion case, excluding CASE-I of low price biomass and simplified system use.

5) This process use is expected to reduce large amount of CO_2 reduction. The merit of RPS credit has big impact, but it is not enough to recover the CO_2 reduction cost, even if the environment tax and CO_2 discharge right are included.

ACKNOWLEDGMENTS

Cost evaluation for biomass collection and transportation is made by Mr. Tatsuo Ohba and Mr. Akiyoshi Kanno of Japan Wood Energy Co., Ltd. Fundamental equations for the biomass cost simulation study are developed by Dr. Koichi Kanzaki, emeritus professor of Koyo University.

REFERENCES

1) "Report for the wood material production volume, 1999" (2000, Forest Agency)
2) A Comprehensive Evaluation System of Coal Quality Impacts on Pulverized Coal Combustion Boilers, S.Kambara and T.Yamada, Effects of Coal Quality on Power Plants 5th Int. Conf., Kansas City (U.S.A), (eds) Harding N.S. and Mehta A.K, 5, 15-29, 1997.
3) A PROPOSAL OF MORE PRACTICAL COAL QUALITY EVALUATION PROCEDURES FOR PULVERIZED COAL COMBUSTION, T.Yamada and S.Kambara, The Effects of Coal Quality on Power Plants 4th Int. Conf., Charleston (U.S.A), (eds) Harding N.S. and Mehta A.K, 4, 51-65, 1994.
4) VDI TERMAL ATRUS Ver. 4 Kd1 (1984)