Prospect and Challenges of Biomass Cofiring
in Coal Power Plant to Support Renewable Energy Mix

Webinar 3

PJB and Japan Biomass Co-Firing Study by Coal Fired Power Plant

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(1). Japanese Biomass Co-Firing Regulations

(a). RPS（Renewable Portfolio Standard）

Issued 2003 to further expand the introduction of new energy by electric utilities by using a certain amount or more of new energy.

- **Article 3 (Target of Electricity such as New Energy)**
  Ministry of Economy, Trade and Industry (METI) sets the goal of electricity use by the electric utilities for the eight years after the relevant year (“Electricity Utilization Target for New Energy").
- **Article 8 (Recommendations and Orders)**
  METI can recommend and order the electric utility shall set a deadline and comply with the provisions.
  If the amount used does not reach the standard without any justifiable reason, METI will order such electric utility.

(**Article 15 (Penalty)**
  A person who violates an order pursuant to the provision of Article 8 shall be punished by a fine of not more than 1 million yen.

Electricity Utilization Target for New Energy

Year	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012
Target TWh	8.67	9.27	10.38	12.43	12.82	3.205 (by June)

The Japanese government has decided to abolish the law in July 2012 and introduce a feed-in tariff (FIT) Law.

(b). Feed-in Tariff Law

- Issued on Aug. 26, 2011, in this law Act on Special Measures on Renewable Energy Electricity Procurement by Electricity Companies was validated.
- The feed-in tariff system for renewable energy was started on July 1, 2012.
- FIT for biomass power generation cofired with fossil fuel will be expired in 2021

Feed-in Tariff for Biomass Power Generation (JPY/kWh)

<table>
<tr><th>Biomass Type</th><th>FY2012</th><th>FY2013</th><th>FY2014</th><th>FY2015</th><th>FY2016</th><th colspan="2">FY2017</th><th>FY2018</th><th>FY2019</th><th>FY2020</th><th>FY2021</th></tr>
<tr><td rowspan="2">Liquidated</td><td colspan="5" rowspan="2">24</td><td>24 *</td><td>21 *</td><td rowspan="2">Bidding</td><td rowspan="2">Bidding</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td colspan="2">24**</td></tr>
<tr><td rowspan="2">General Wood etc.</td><td colspan="5" rowspan="2">24</td><td>24 *</td><td>21 *</td><td>Bidding ***</td><td>Bidding ***</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td colspan="2">24**</td><td>24****</td><td>24****</td></tr>
<tr><td rowspan="2">Unused Material</td><td colspan="3" rowspan="2">32</td><td colspan="8">40(＞2000kWh)</td></tr>
<tr><td colspan="8">32 (≦2000kWh)</td></tr>
<tr><td>Construction Waste</td><td colspan="11">13</td></tr>
<tr><td>Methane Ferment</td><td colspan="11">39</td></tr>
<tr><td>Municipal Solid of waste</td><td colspan="11">17</td></tr>
</table>

*:20MWover, **;20MWbelow, ***:10MWover, ****:10MWbelow

(2). Japanese Biomass Co-Firing Plants by PC Boiler

for Existing PC Boiler Plants in Utility Services , 18Units, 735GWh/y, reducing 870,000 tonCO2/y

No.	Electric Utility Name	Power Station Name	Unit No.	Out Put MW	Steam Condition	COD	Supplier		Co-firing Date	Co-firing Rate % (W=weight, H=Heat)	Biomass Type	Biomass Weight Ton/Y	Biomass Output MWh/Y	CO2 Reduction Ton/Y
							Boiler	Turbine						
1	Tokyo	A	1	1,000	USC	2003/12/1	HITACHI	HITACHI	2017/6/1	Max.3%W	Wood Pellet	150,000	150,000	220,000
2			2	1,000	USC	2014/6/1	HITACHI	HITACHI	2017/10/1	Max.4.5%W	Wood Pellet			
3	Hokuriku	B	2	700	USC	2000/10/1	MHI	TOSHIBA	2007/6/1	0.3%H	Wood Saw Dust	15,000	12,500	11,000
4		C	2	700	USC	1998/7/1	IHI	TOSHIBA	2010/9/1	0.4%H	Wood Saw Dust	20,000	17,000	14,000
5	Chubu	D	1	700	SC	1991/10/1	HITACHI	TOSHIBA	2010/9/17	3%W	Wood Biomass	300,000	300,000	300,000
6			2	700	SC	1992/6/1	HITACHI	HITACHI						
7			3	700	USC	1993/6/1	IHI	MHI						
8			4	1,000	USC	2001/11/1	IHI	TOSHIBA						
9			5	1,000	USC	2002/11/1	IHI	TOSHIBA						
10	Kansai	E	1	900	USC	2004/8/1	MHI	MHI	2008/8/29	3%W	Wood Pellet	60,000	60,000	92,000
11			2	900	USC	2010/8/1	IHI	TOSHIBA	2022/8/1	3%W	Wood Pellet	60,000	60,000	92,000
12	Chugoku	F	3	500	SC	1986/4/1	IHI	TOSHIBA	2013/9/1	1%H	Wood Biomass	35,000	35,000	29,000
13			4	500	SC	1987/2/1	IHI	TOSHIBA						
14		G	1	1,000	USC	1998/7/1	MHPS	MHPS	2013/9/1	0.5%H	Wood Biomass	30,000	32,000	23,000
15	Kyushu	H	1	700	SC	1995/12/1	IHI	TOSHIBA	2015/1/1	1%W	Wood Chip	15,000	15,000	10,000
16	Okinawa	I	1	156	Sub-C	1994/3/1	KHI	HITACHI	2010/3/25	2%H	Wood Pellet	20,000	20,000	30,000
17			2	156	Sub-C	1995/3/1	HITACHI	MHI						
18	J-Power	J	2	1,000	USC	1997/7/1	HITACHI	MHI	2004/5/25	0.5%H	Wood Chip	31,000	32,000	48,000
Sub Total												**736,000**	**733,500**	**869,000**

Source: JCOAL

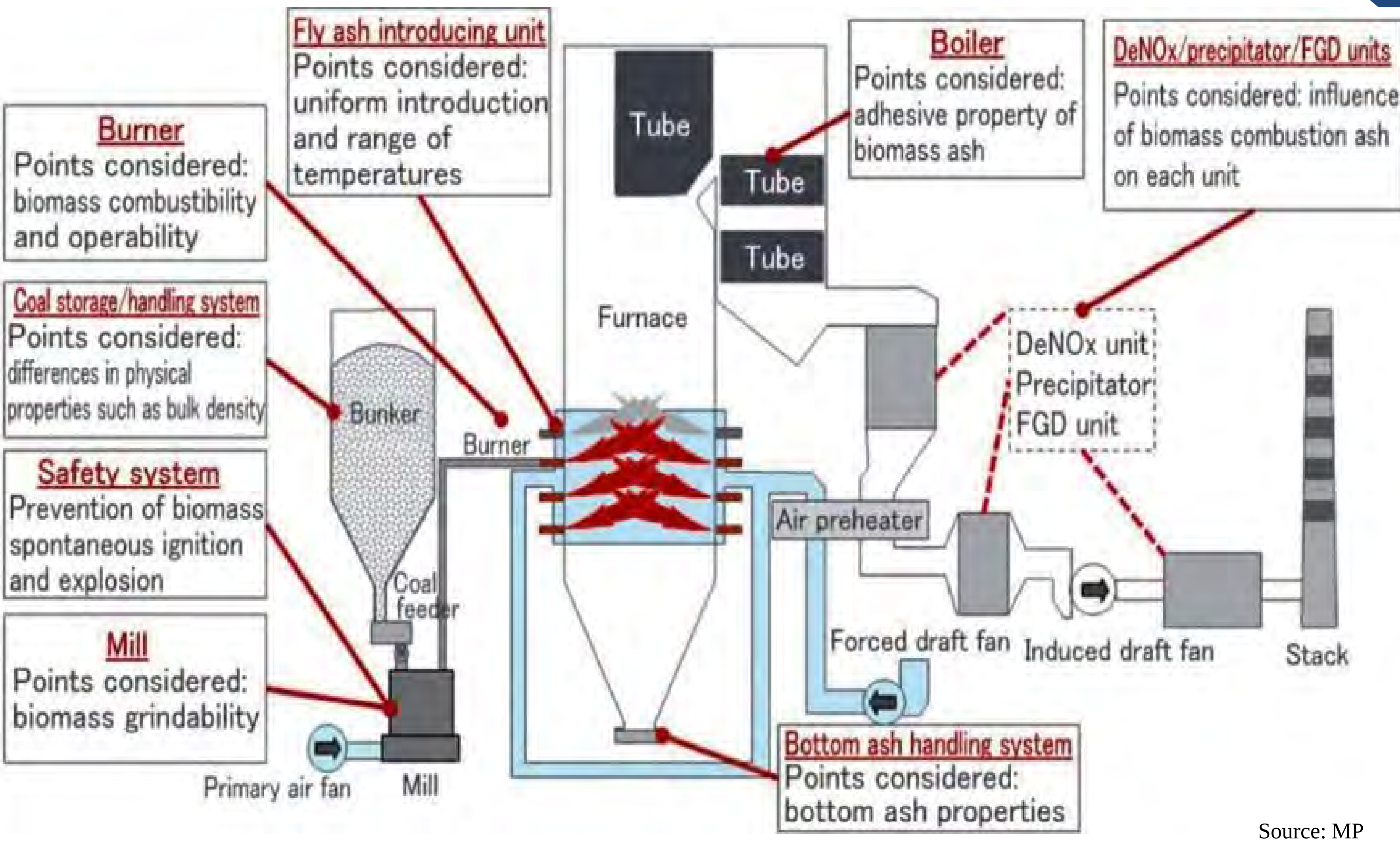
(3). Japanese Biomass Co-Firing Plants by CFB Boiler

More than 20 Units , 10,200GWh/y were successfully operated from 2011 reducing 7,950,000 tonCO2/y .

No.	Gov. Regulation	End User	Industry	City	Out Put MW	Steam Condition	COD	Biomass firing Date	Co-firing Rate (Calorific Value)	Biomass Fuel	Biomass Output MWh/year	CO2 Reduction (tCO2/year)
1	FIT	ISHINOMAKI BIO ENERGY	IPP	ISHINOMAKI	75	Sub-C (RH)	May-23	May-23	100%	Wood Chip, PKS	600,000	463,400
2	FIT	HIROHATA BIOMASS	IPP	HIROHATA	75	Sub-C (RH)	Jul-23	Jul-23	100%	Wood Chip, PKS	600,000	463,400
3	FIT	OJI GREEN ENERGY TOKUSHIMA	IPP	ANAN	75	Sub-C (RH)	Sep-22	Sep-22	100%	Wood Chip, PKS	600,000	463,400
4	FIT	ABLE ENERGY	IPP	IWAKI	112	Sub-C (RH)	Apr-22	Apr-22	100%	Wood Pellet	896,000	692,000
5	FIT	KANDA BIOMASS ENERGY	IPP	KANDA	75	Sub-C (RH)	Jun-21	Jun-21	100%	Wood Pellet, PKS	600,000	463,400
6	FIT	BIO POWER KANDA	IPP	KANDA	75	Sub-C (RH)	Oct-21	Oct-21	100%	Wood Pellet, PKS	600,000	463,400
7	FIT	SHIMONOSEKI BIOMASS ENERGY	IPP	SHIMONOSEKI	75	Sub-C (RH)	Jan-22	Jan-22	100%	Wood Pellets, PKS	600,000	463,400
8	FIT	CHUBU ELECTRIC	IPP	YOKKAICHI	49	Sub-C	Apr-20	Apr-20	100%	Wood Pellets, PKS	392,000	463,400
9	FIT	KAITA BIOMASS POWER	IPP	KAITA	112	Sub-C (RH)	Mar-21	Mar-21	100%	Wood Pellets, Wood Chips, Coal	896,000	692,000
10	FIT	MURORAN BIOMASS POWER	IPP	HOKKAIDO	75	Sub-C (RH)	May-20	May-20	100%	PKS	600,000	463,400
11	FIT	AIR WATER & ENERGIA POWER	IPP	HOFU	112	Sub-C (RH)	Jul-19	Jul-19	50%	Wood Chip, PKS, Coal	896,000	692,000
12	FIT	SUMMIT SAKATA POWER	IPP	SAKATA	50	Sub-C	Jul-18	Jul-18	100%	Wood Chip, PKS, Wood Pellet, Coal	400,000	308,900
13	FIT	TSURUGA GREEN POWER	IPP	TSURUGA	37	Sub-C	Jul-17	Jul-17	85%	Coal, Wood Chip	296,000	228,600
14	FIT	SUMMIT HANDA POWER	IPP	HANDA	75	Sub-C (RH)	Dec-16	Dec-16	100%	Wood Chip	600,000	463,000
15	FIT	OJI GREEN ENERGY	IPP	HOKKAIDO	25.0	Sub-C	Dec-16	Dec-16	80%	Coal, Wood Chip	200,000	154,500
16	FIT	UNITED CORPORATION	IPP	AKITA	20	Sub-C	Jun-16	Jun-16	100%	Palm Kennel Shell, Wood Chip	160,000	124,000
17	FIT	MOMBETSU BIOMASS POWER	IPP	MOMBETSU	50	Sub-C	Nov-16	Nov-16	70%	Coal, Wood Chip	400,000	308,900
18	FIT	OJI GREEN ENERGY	IPP	NICHINAN	25.0	Sub-C	Apr-15	Apr-15	80%	Coal, Wood Chip	200,000	154,500
19	RPS	KAWASAKI BIOMASS POWER	IPP	KAWASAKI	33	Sub-C	Feb-11	Feb-11	100%	Wood Chip	264,000	203,900
20	RPS	SUMMIT MYOJYO POWER	IPP	ITOIGAWA	50	Sub-C	Oct-04	Oct-04	70%	Coal, Demolition Wood	400,000	221,300
					1200					Sub Total	10,200,000	7,950,800

*1: 20% Coal *2: 50% Coal *3: 15% Coal *4 30% Coal *5: 20% Coal *6: 20% Coal

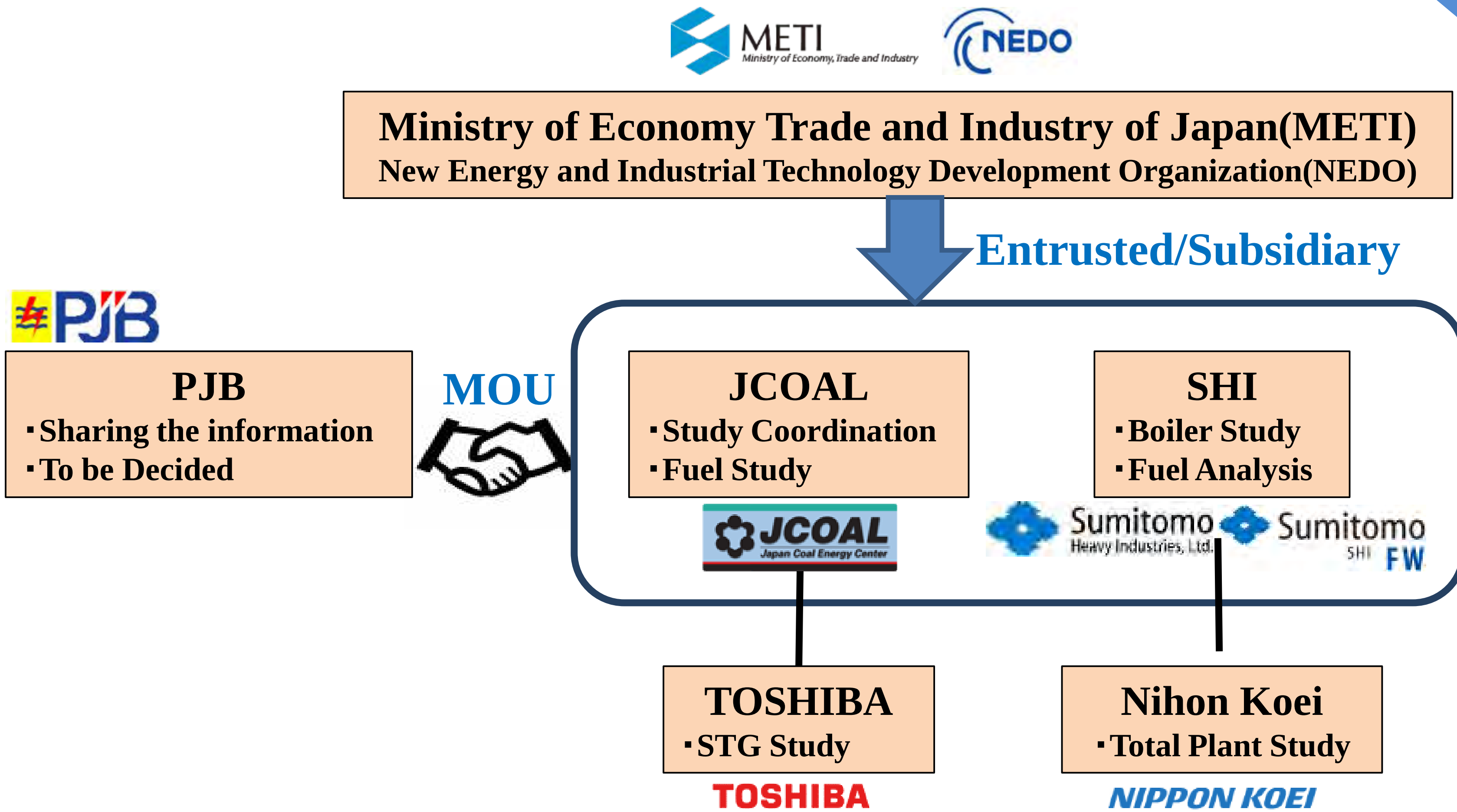
(4). Challenges in Biomass Co-firing by PC Boiler



Source: MP

2. PJB and Japan Biomass Co-firing Study

Study Scheme



(STEP1). Biomass Co-firing Study by PC Boiler

(STEP2). Biomass Co-firing Study by USC-CFB Boiler

(STEP1) Biomass Co-Firing Study by PC Boiler

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(1). CO2 Emission Simulation on PLTU Paiton

100%Coal and 3 Co-firing Rates of 4 Biomass Fuels were simulated on 3 Coals.
CO2 Emission per MW is evaluated in each cases.

Coal-fired Power Plant			Paiton Power Station 400MW Class (Simulation)									
(a) Out Put		MW	400	400			400			380		
(b) Co-firing			Coal 100%	Co-firing with coal 4700			Co-firing with coal 4500			Co-firing with coal 4000		
(c) Fuel Mixing Ratio			100% All Coal	5% Sawdust	30% Wood Pellet	5% Sawdust 10% Rice Husk 15% Fine Wood Chip	5% Sawdust	30% Wood Pellet	5% Sawdust 10% Rice Husk 15% Fine Wood Chip	5% Sawdust	30% Wood Pellet	5% Sawdust 10% Rice Husk 15% Fine Wood Chip
(e) Cord No.			P3	M1a	M1b	M1c	M1a	M1b	M1c	M2a	M2b	M2c
1. Fuel Consumption												
Load maximum		MW	400.00	400.00	400.00	400.00	400.00	400.00	400.00	380.00	380.00	380.00
Biomass Output		MW	0.00	20.00	120.00	120.00	20.00	120.00	120.00	19.00	114.00	114.00
Plant Efficiency	HHV	%	36.0	36	36	36	36	36	36	33.1	33.3	32.9
Calorific Value (AR)	HHV	kcal/kg	4,506	4,480	4,594	3,980	4,360	4,501	3,906	3,986	4,202	3,669
Coal consumption		t/hr	212	196	144	144	201	148	148	229	168	170
Sawdust		t/hr		18		18	18		18	18		18
Rice Husk		t/hr				28			28			29
Fine Wood chip		t/hr				40			40			42
Wood pellet		t/hr			64			64			66	
Total		t/hr	212	213	208	230	219	212	234	247	234	259
2. CO2 Emission												
House load		%	7	7	7	7	7	7	7	7	7	7
CO2 Emission		kg-CO2/hr	357,269	336,690	248,088	248,088	339,405	250,088	250,088	361,705	265,719	268,949
CO2 Emission per MW (gross)		g-CO2/kWh	893	842	620	620	849	625	625	952	699	708
CO2 Emission per MW		g-CO2/kWh	**960**	**905**	**667**	**667**	**912**	**672**	**672**	**1,023**	**752**	**761**

The above is prepared for the purpose of a case study of a CO2 emission for PLTU Paiton and is **NOT** for the purpose of an evaluation of Biomass Co-firing technology

(2). Comparison of Biomass Fuel and Coal in Indonesia

Parameter	Unit	Coal		Biomass				
		Bituminous	Sub-Bituminous	Wood Pellet	Palm Kernel Shell	Sawdust Sawmill	Woodchip Lamtoro	Rice Husk Pasuruan
		Ar	Ar	Ar	Ar	Ar	adb	Ar
Ultimate								
Carbon	%	48.61	43.82	48.51	48.01	40.97	49.03	37.37
Hydrogen	%	3.75	3.37	3.19	5.51	4.38	6.03	4.83
Nitrogen	%	1.09	0.68	0.24	0.18	0.30	0.22	0.32
Oxygen	%	13.95	13.22	42.16	33.30	36.79	44.12	27.67
Proximate								
Total Moisture	%	24.32	35.84	4.50	12.21	41.74	9.52	11.43
Ash content	%	7.66	2.96	1.27	0.74	2.01	0.49	18.31
Volatile matter	%	34.43	30.97	79.87	68.67	46.25	83.16	57.49
Fixed carbon	%	33.59	30.24	14.36	18.38	10.00	16.35	12.77
Total Sulphur	%	0.63	0.11	0.13	0.05	0.07	0.10	0.07
Gross calorific value	kcal/kg	4,897	4,199	4,449	4,543	2,694	4,140	3,383
Hargrove Grindability Index		47	55	<32,00	<32	<32	-	25
Ash Composition (dry base)								
Silica dioxide SiO_2	%	42.98	52.14	3.56	65.44	26.00	15.29	69.70
Sodium Oxide Na_2O	%	0.51	0.85	0.82	7.8	2.06	0.92	0.10
Potassium Oxide K_2O	%	0.59	0.81	12.92	3.16	12.12	9.86	1.02

BIOMASS ADVANTAGE: 1. Free CO_2 2. Low Total Sulfur 3. Low Ash Content
DISADVANTAGE: 1. High Moisture 2. Low Calorie 3. High Potassium :K

Potassium:K_2O makes lower ash melting temp. in furnace.

Element	Oxide	Melting temp.°C
Si	SiO_2	1,716
Na	Na_2O	1,277
K	K_2O	349

PC Boiler Furnace Inside Temp.=1,400℃

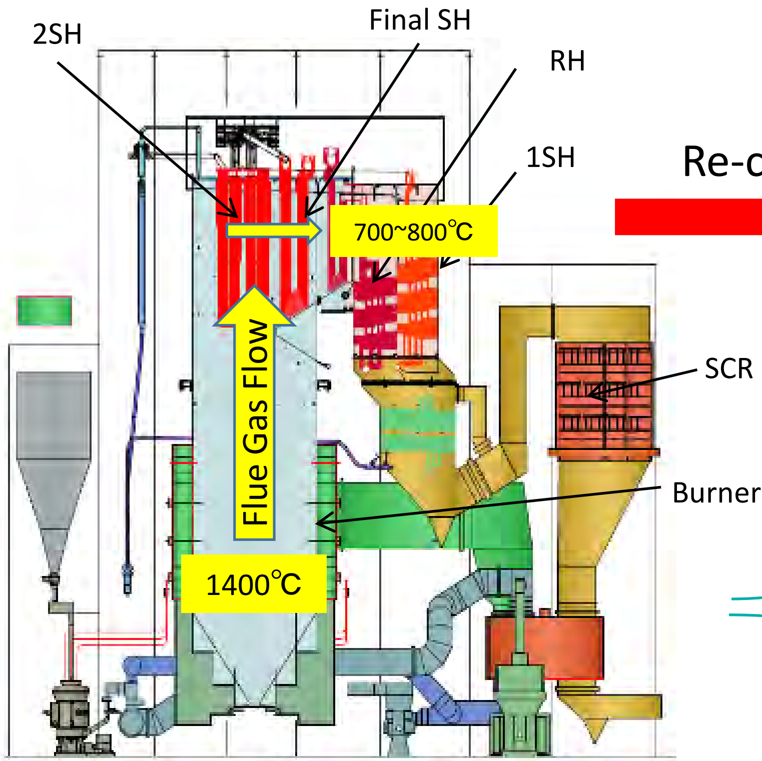
Compound	Melting temp.°C	Chemical Property
Na_2SiO_3	877	Acidic
K_2SiO_3	977	Acidic

Source "Combustion Fossil Power Systems/Combustion Engineering", USA

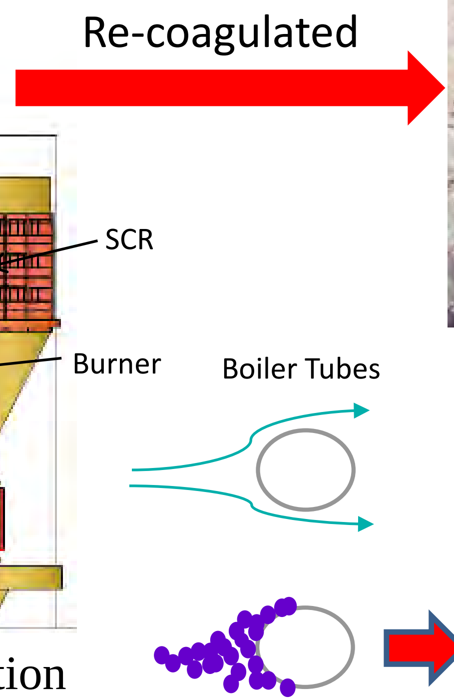
(3). Typical Slagging and Fouling Damage in PC Boiler

High Na and K fuels have low ash melting points which cause Fouling and Slagging in PC Boilers

- Slagging Area: Temperature between melting point and evaporation point of ash = 1SH
- Fouling Area : Melted ash sticking to heat exchange surfaces = Boiler Tubes



Typical PC Boiler Configuration



(4). Challenges in Biomass Co-firing by PC Boiler and Advantages of USC-CFB Boiler

		PC Boiler				USC-CFB Boiler		
1. Biomass Co-firing ratio								
(calorific value base)		1%	3%	5%	10-30%	10%	20%	50%
(weight base) (+30%)		<2%	abt. 4%	6-7%	13-39%	13-19%	26%	65%
2. Coal (HHV kcal/kg)		Sub-Bituminous(4,500-4,700)				Low grade(3,500-4,200)		
3. Biomass Type Applicability	(Fuel Cost)							
Sawdust	(Low)			Applicable as long as collected		Applicable as long as collected		
Wood Chip								
Wood White Pellet								
Black Torrefied Pellet	(High)	Applicable		Facility Modification Required		Applicable		
EFB Pellet								
OPT (Oil Palm Trunk Pellet)								
PKS (size: 10-20mm)	(High)			Applicable (but high HGI)		Applicable	Depends on Aggregation	
4. Recommended Facility Modification								
Mill Modification				One set	at least Two sets			
Burner Modification				Modified as sets of Modified Mills		Can be handled in any case		
Primary Fan System Modification				Review Fan Capacity and Modified				
5.Issues of Operation & Maintenance			Mill grinding ability is down and the aux. power increased abt. 20%	Wood chips or pellets may meet 1/7-1/10 of coal grindability, if no modified mill(s).	Depend on Slagging/Fouling conditions due to ash low fusion temperature by high Na_2O & K_2O in ash.	**No issues for Long Term Operation**		
6. CO2 Emission g CO2/kWh						less than 700	about. 600	less than 400

(STEP2) Biomass Co-firing by USC-CFB Boiler

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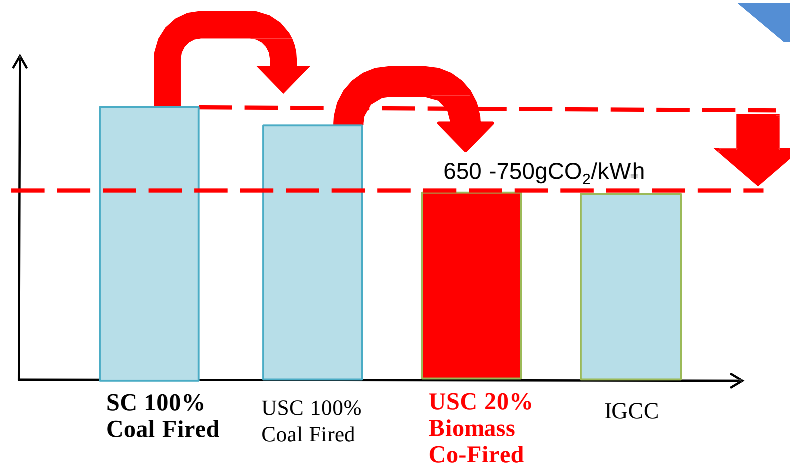
(1). Project Survey utilizing USC-CFB(circulating fluidized bed) Boiler

- Purpose: Reduction of CO2 emissions
  CO_2 emissions can be reduced by more than 30% (similar to IGCC) by application of USC (ultra-supercritical pressure)- CFB boiler and Biomass Co-firing (30 to 50%) .



CO_2 Emission of Power Generation

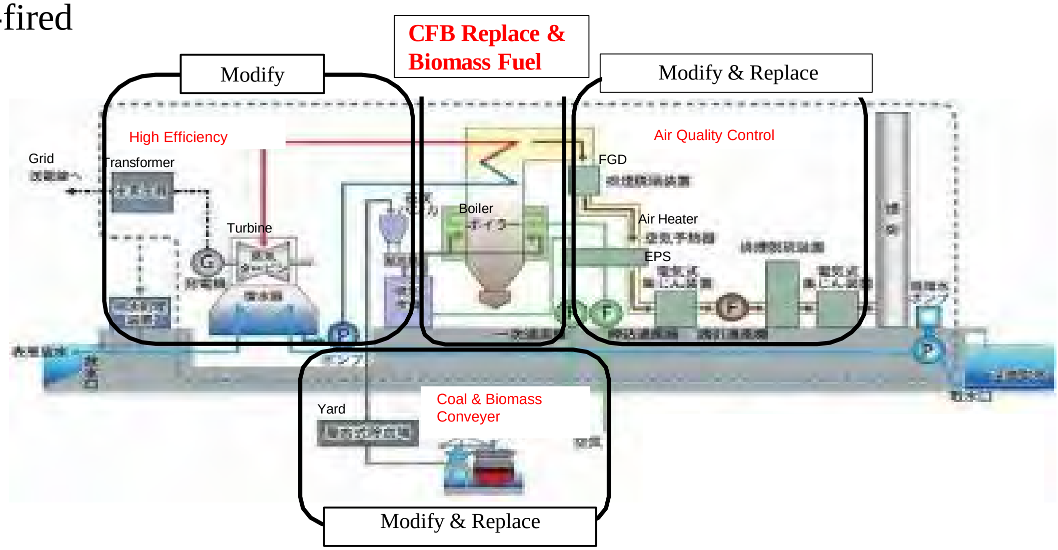
SC: Supercritical USC:Ultra-Supercritical

(2). Survey Items

- Existing Sub-C PC Boiler in PLTU Paiton will be replaced to CFB-USC Boiler and co-fired with Biomass fuel.

1. Requirement of modification of existing PLTU in Indonesian Regulations
2. Supply Chain for Biomass Fuels to PLTU Paiton
3. Power System Requirement in Jawa-Bali Grid
4. Conceptual Design for Paiton Modification
5. Economic Analysis

- PLTU Modification Plan



(3). CFB Technology Feature with 5 Advantages

1.Fuel flexibility

Wide Fuel Range

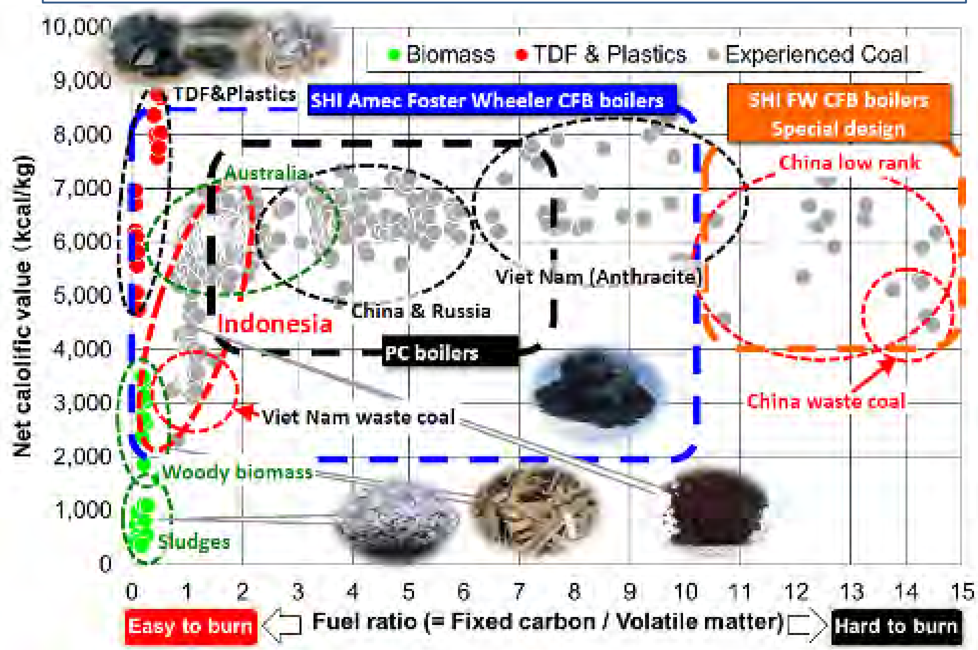
Circulating solids provide high thermal inertia for stable combustion over a wide range of fuels

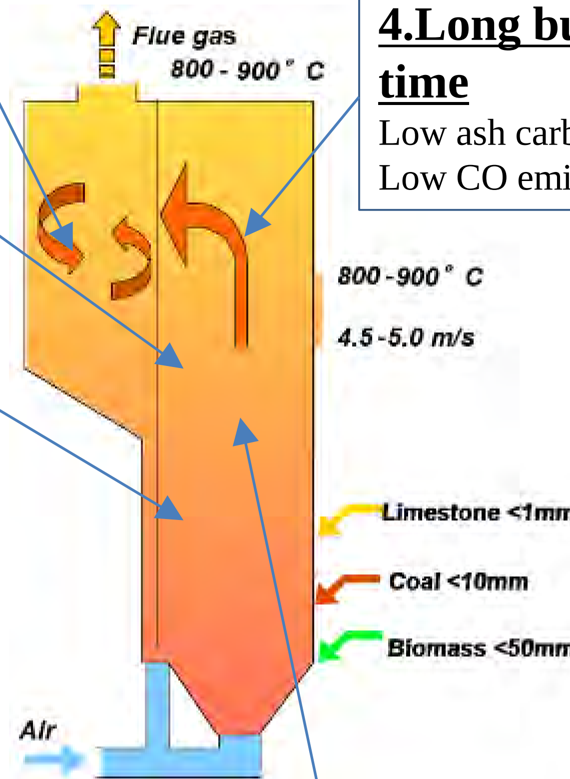
2.Very low NOx levels

Excellent mixing in cyclones minimizes ammonia slip- Stringent NOx limits can be achieved SCR catalyst.

3.Sulfur captured in furnace

Effective and economical sulfur capture in furnace by using Limestone. Calcium rich ash can be reactivated for further SOx reduction. recycled or landfilled





4.Long burning time

Low ash carbon content
Low CO emissions

5.Low maintenance

No ash slagging which minimizes furnace corrosion and fouling - Circulating solids keep furnace surface clean and minimize deposit build up.

Source: SHI

(4). Possible fuel cost reduction before Co-firing by USC-CFB Boiler

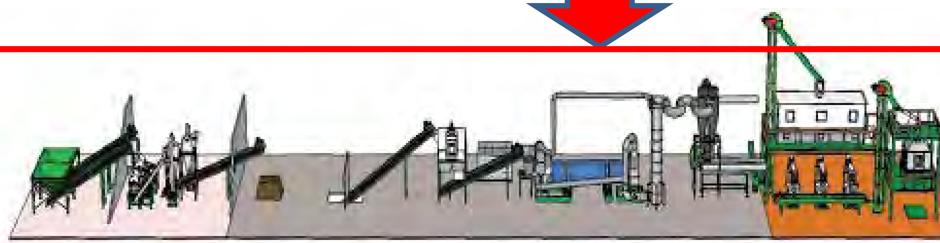
- CFB accepts less preparation for wider range Biomass fuels without high cost investment .

Typical Biomass Sources: ***How to supply enough volume of low-cost Biomass is the matter in Indonesia.***

Wood Chipping

Woodchips
(Cheaper)

CFB Boiler



1. Grinding 2. Drying 3. Pelletizing

Additional Investment for PC Boiler

Wood Pellets

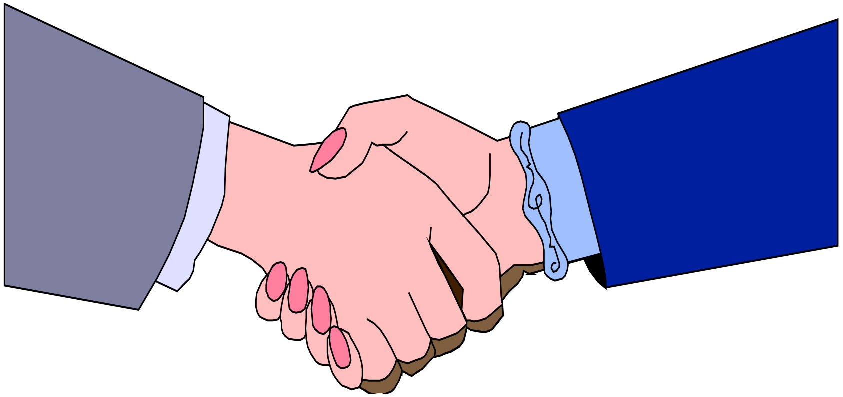
PC Boiler

(5). Schedule of Feasibility Study for PLTU Paiton

Contents of Feasibility Study	2020 1Q	2020 2Q	2020 3Q	2020 4Q	2021 1Q	2021 2Q	2021 3Q	2021 4Q
1. Biomass Fuel Research & Co-Firing Study Biomass Sampling Analysis	STEP 1	STEP 1	STEP 1	STEP 1				
2. Plant Design for replacement to CFB Boiler (Basic Design Concept for Rehabilitation) Construction Schedule Planning			STEP 2	STEP 2	STEP 2			
3. CO2 reduction calculation Financial Evaluation					STEP 2	STEP 2		
4. Final Report to PJB (Expected)						▼		
5. Continuous Discussion toward COP26 & COD							→	→

In order to achieve Indonesian “RE” target of 23% of total installed capacity as announced in COP25, this F/S aims for proposing best solution to Indonesia.

Thank you for your attention!
Terima kasih!
Arigatou Gozaimashita!



Website:
http://www.jcoal.or.jp/index-en.html

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