

**75<sup>th</sup> IEA-FBC Meeting, Skive, Denmark**

# **Fluidized Bed Gasification and Combustion of Biomass**

**IHI**

**October 24<sup>th</sup>, 2017**

**IHI Corporation**

**Resources, Energy & Environment Business Area**

**Tomoyoshi Kumagai**

# Table of Contents

**CHAPTER 1** Introduction

**CHAPTER 2** Biomass fuels in IHI's experience

**CHAPTER 3** Biomass combustion and gasification technologies

**CHAPTER 4** Conclusion

# CHAPTER 1

## Introduction

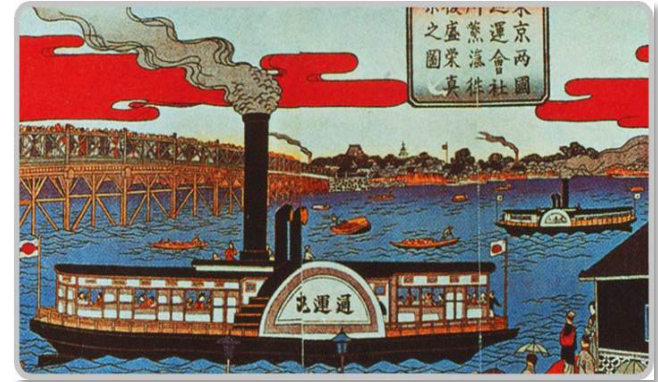


# IHI Corporation Profile

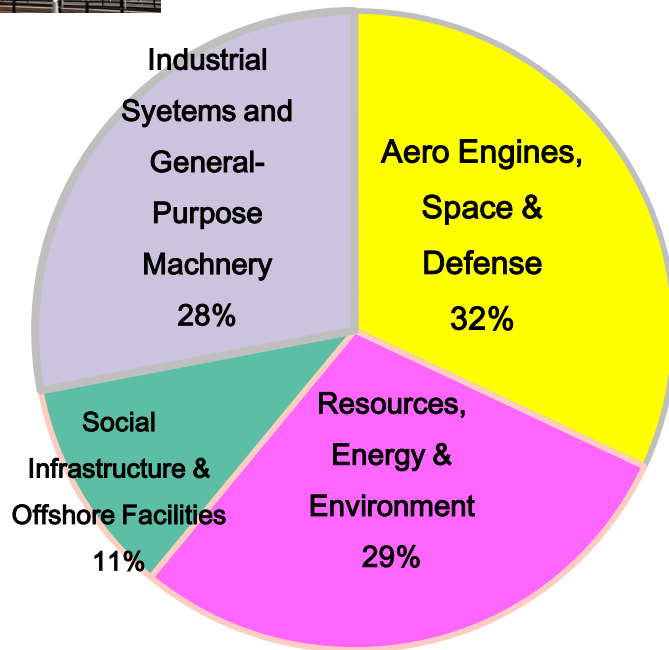


**Established:** 1853 (164<sup>th</sup> Anniversary in 2017)  
**Capital:** 107.1 Billion JPY (0.9 Billion USD)  
**Employees:** 29,659  
**Affiliated companies:** 84 (in Japan) 175 (in Overseas)  
**Net sales:** 1,486.3 Billion JPY (12.6 Billion USD)

--Information is on consolidated basis and is corrected as of March 2017--



The First Steamship Built by Japanese Private Company – “Tsu-un maru”.  
 “Ishikawajima Hirano Shipyard”



**Total Sales Volume**  
 (Year end March, 2017)



**Global Network**

● Overseas Office ● Global Subsidiary Company



# IHI Business Areas

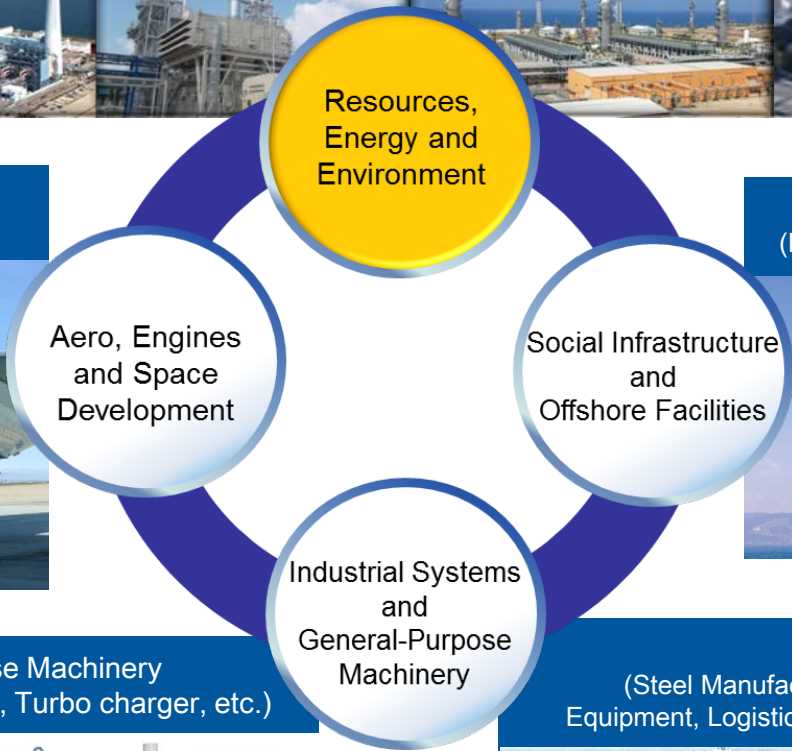
**Resources, Energy and Environment**  
(Boiler, Gas Turbine/Gas Engine, LNG Terminal, Process Plant, Nuclear Equipment, etc.)

**Aero Engines and Space**  
(Jet Engine, Rocket)

**Social Infrastructure and Offshore Facilities**  
(Bridge, Transportation System, Security, etc.)

**General-Purpose Machinery**  
(Compressor, Separator, Turbo charger, etc.)

**Industrial Systems and General-Purpose Machinery**  
(Steel Manufacturing Furnaces, Heat/Surface Treatment Equipment, Logistics Systems, Material Handling Equipment, etc.)



# Introduction

- IHI has developed the technologies for reduction of CO<sub>2</sub> emissions. An effective approach is biomass utilization.

- 100% biomass fuel utilization has been realized by IHI Fluidized Bubbling Bed boiler (FBB) and Circulating Fluidized Bed boiler (CFB) technology.

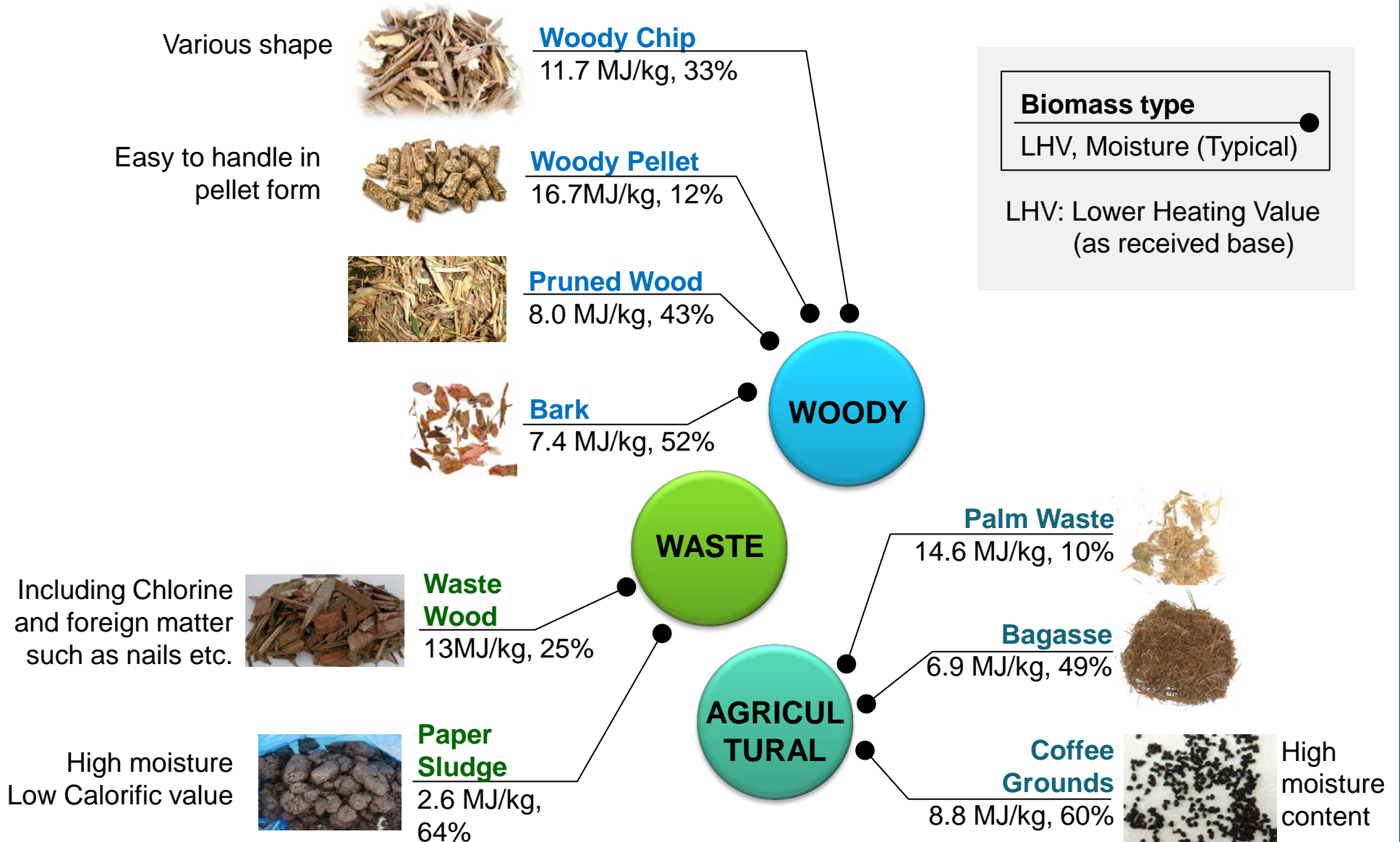


- Moreover, from the successful boiler technologies, Twin IHI Gasifier (TIGAR®) has been developed for both coal and biomass gasification to be utilized for various applications – chemical production, power generation, methanation, etc. 100% biomass gasification and co-gasification of lignite and biomass has been achieved.

## CHAPTER 2

# Biomass fuels in IHI's experience

# Examples of Biomass



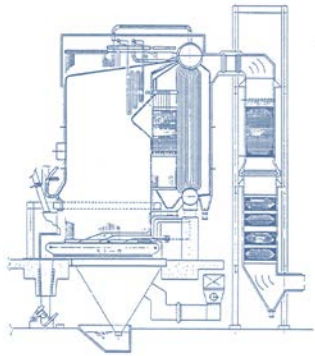


## **CHAPTER 3**

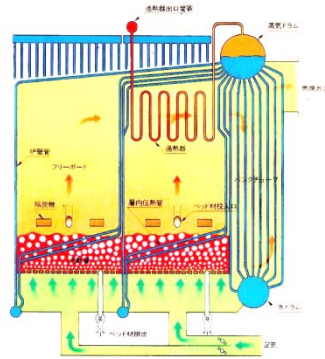
# **Biomass combustion and gasification technologies**

# Biomass fired combustion and gasification technologies

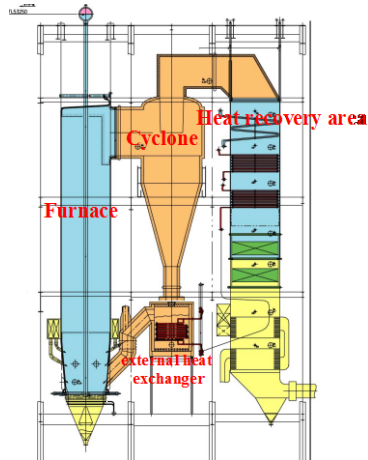
## Combustion



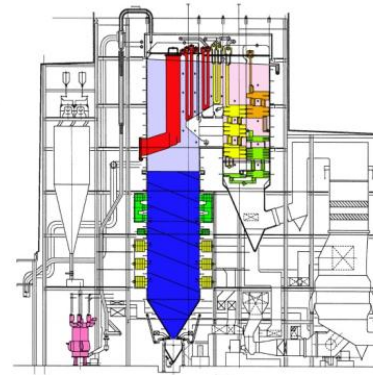
Stocker Boiler



Fluidized Bubbling Bed Boiler (FBB)



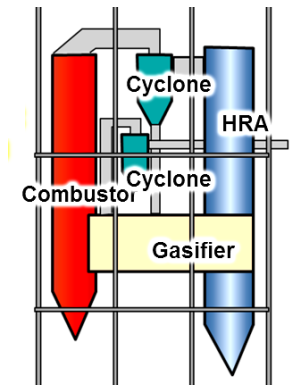
Circulating Fluidized Bed Boiler (CFB)



Pulverized Coal Fired Boiler (PCFB) with co-combustion of biomass



## Gasification

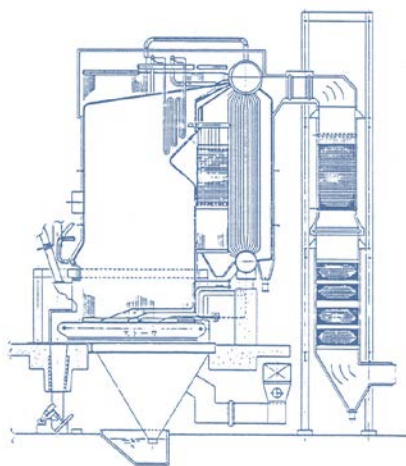


Twin IHI Gasifier (TIGAR®)

IHI's products line-up on biomass utilization technologies

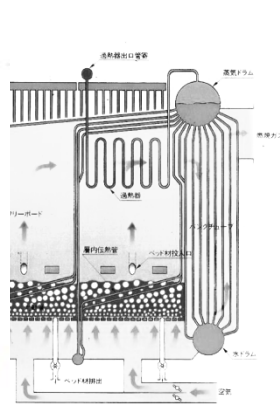
# Biomass fired combustion and gasification technologies

## Combustion

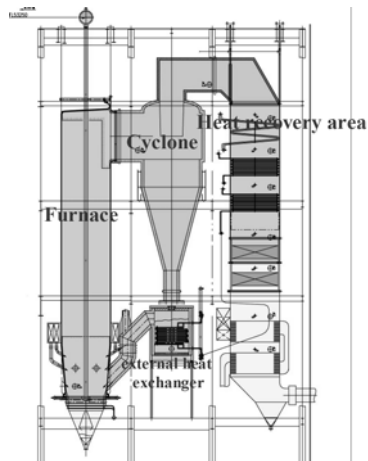


### STOCKER BOILER

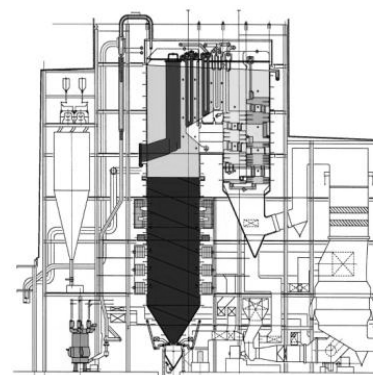
mostly delivered in 1970's and early 1980's



Fluidized Bubbling Bed Boiler (FBB)

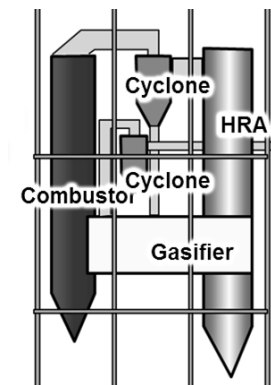


Circulating Fluidized Bed Boiler (CFB)



Pulverized Coal Fired Boiler (PCFB)

## Gasification



Twin IHI Gasifier (TIGAR®)

## IHI's experience in biomass



Bark



Bagasse



Waste wood



Palm waste

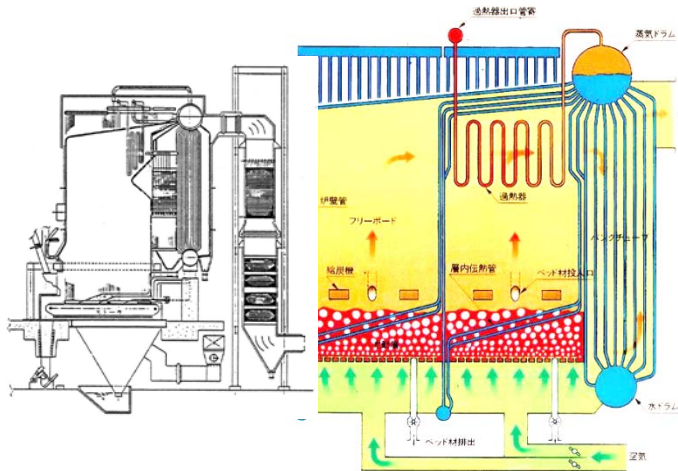
## Co-combustion ratio of biomass

100%  
(Bagasse / Palm waste)  
**In the commercial units**



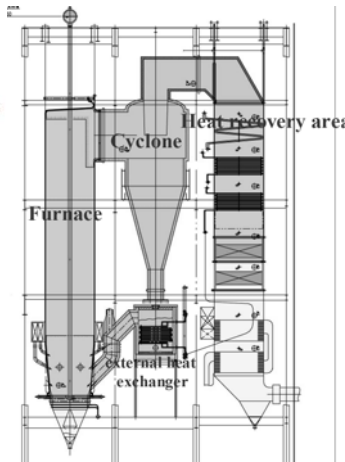
# Biomass fired combustion and gasification technologies

## Combustion

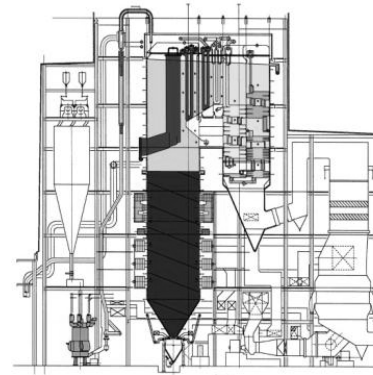


Stocker Boiler

**FLUIDIZED BUBBLING BED BOILER (FBB)**

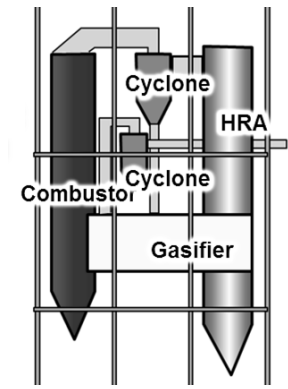


Circulating Fluidized Bed Boiler (CFB)



Pulverized Coal Fired Boiler (PCFB)

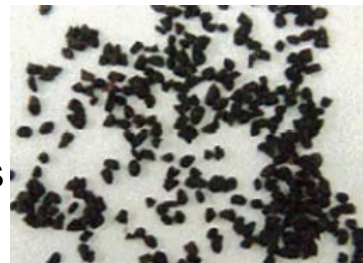
## Gasification



Twin IHI Gasifier (TIGAR®)

## IHI's experience in biomass

Coffee grounds  
Coffee Sludge



### Coffee Grounds

LHV: 8.8 MJ/kg  
Moisture: 60%

**Without support firing**

### Co-combustion ratio of biomass

100%  
(Coffee grounds)  
**In the commercial units**



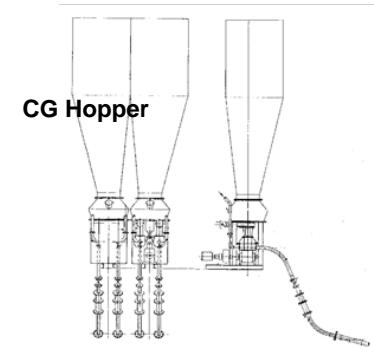
# Fluidized Bubbling Bed Boiler (FBB)

## Features of Biomass Fired FBBs

	NESTLE HIMEJI (JAPAN)	NESTLE MALAYSIA
BOILER OUTLINE		
STEAM EVAPORATION	40t/h	11t/h
FUEL	55% Moisture Coffee Grounds + Coal	60% Moisture Coffee Grounds

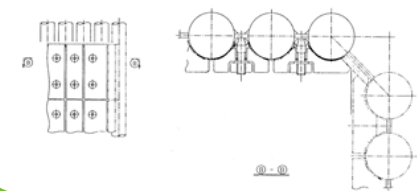
### Suitable Fuel Supply System

(Pneumatic fuel supply nozzles:  
Fuel supply in bed)



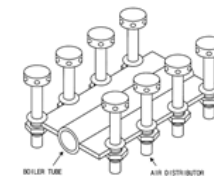
### Wear-Resistant Block

- High anti-erosion performance
- Easy installation



### Air Distributer

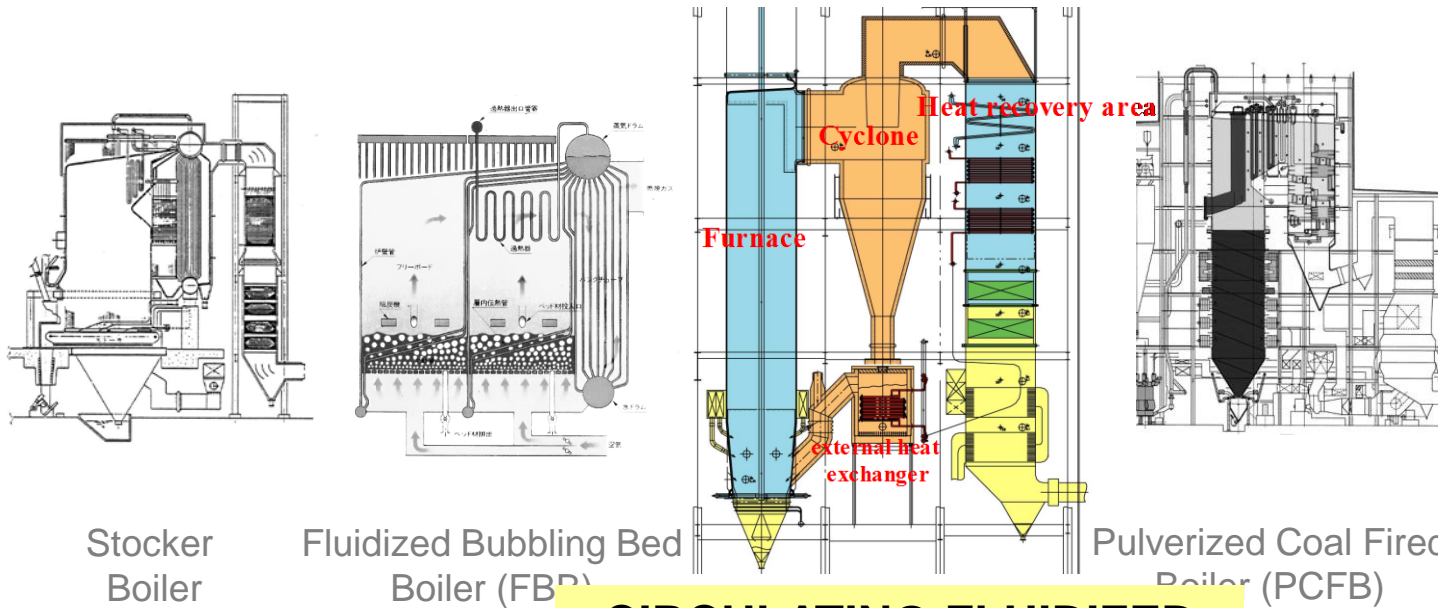
- Uniform air distribution at furnace bottom



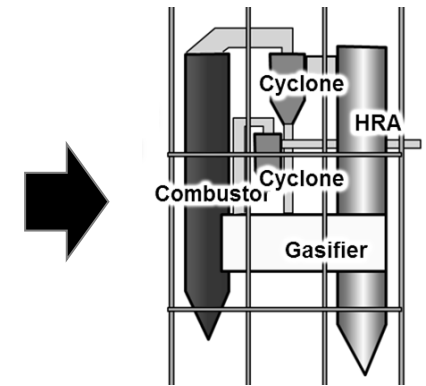
**IHI**

# Biomass fired combustion and gasification technologies

## Combustion



## Gasification



## CIRCULATING FLUIDIZED BED BOILER (CFB)

### IHI's experience in biomass



Woody chip



Bark



Pruned wood



Palm waste



Waste wood



Paper Sludge

### Co-combustion ratio of biomass

100%  
(Palm waste)

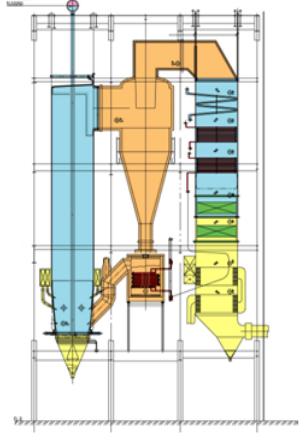
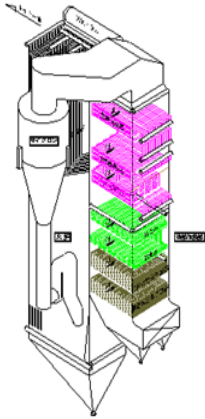
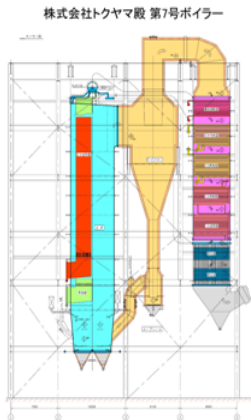
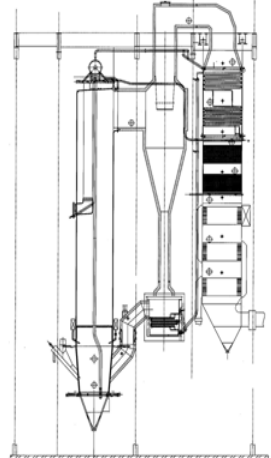
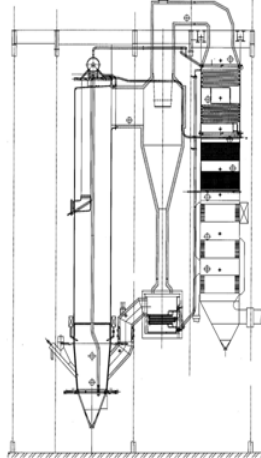
**In the commercial units**

**IHI's experience in waste fuel:** : Waste tire, RPF, Waste plastic, Factory waste

**IHI**

# Circulating Fluidized Bed Boiler (CFB)

## Experience of Biomass Fired CFBs

Deliver to	Oji Paper Co., Ltd Tomakomai Mill	Nippon Paper Group, Inc. Ishinomaki Mill	Tokuyama Corp. Tokuyama Works	Nippon Paper Group, Inc. Iwakuni Mill	Nippon Daishowa Paperboard Yoshinaga Co., Ltd
Evaporation	260 t/h	180 t/h	310 t/h	180 t/h	180 t/h
Steam Condition	12.35MPa/569°C	8.33MPa/505°C	10.3MPa/541°C /541°C	10.3MPa/505°C	10.6MPa/513°C
Fuel	RPF/Coal/Paper Sludge /Bark/Waste Tire /Wood Tip	Wood Tip/RPF/Coal /Paper Sludge /Factory Waste	Coal/Waste Tire /Palm Waste	Wood Tip/RPF/ Coal/Waste Tire /Waste Plastic	Wood Tip/Pruned Wood Coal/RPF
Completed in	2004	2006	2008	2008	2008
					
Remarks	First Biomass CFB/High Steam Temp.	Compact Arrangement	First CFB with RH		

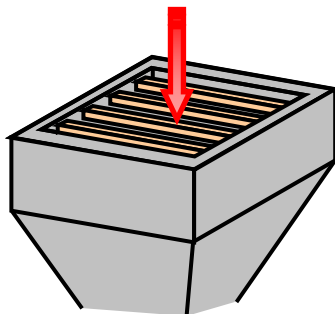
# Circulating Fluidized Bed Boiler (CFB) Characteristics of IHI's CFB

## ■ Furnace

- ✓ High combustion efficiency
- ✓ Simple furnace temperature control

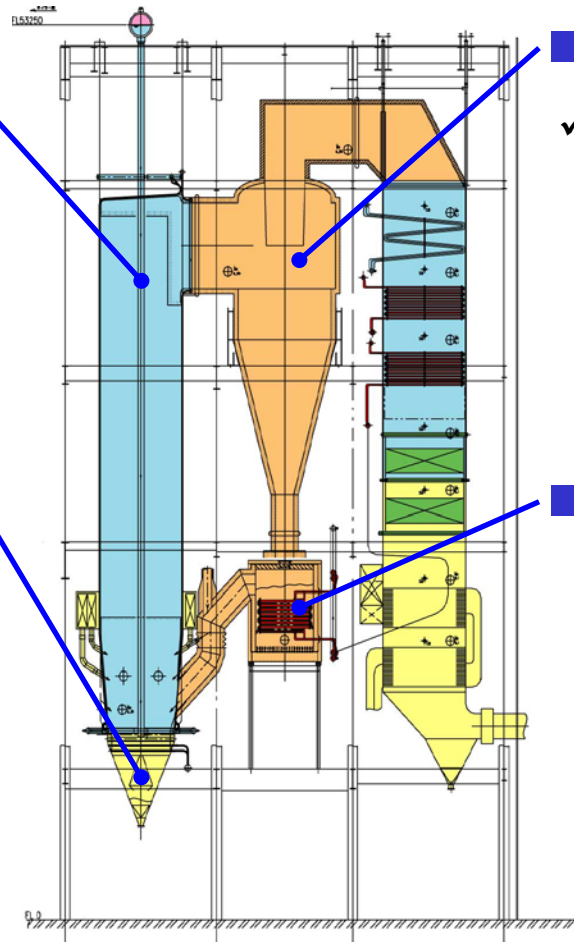
## ■ Open type bottom

- ✓ Furnace bottom is open bottom type and it can easily discharge foreign materials such as nails included in waste wood and bead wires included in waste tire.



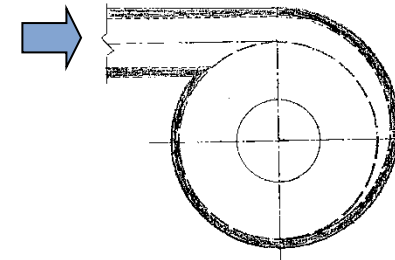
Bead wires from waste tire    Nails from waste wood

## Examples of discharged foreign materials



## ■ Round cyclone

- ✓ High collection efficiency



## ■ External heat exchanger

- ✓ External heat exchanger can recover the heat while avoiding corrosion problem on hot heating elements due to chlorine in Biomass.



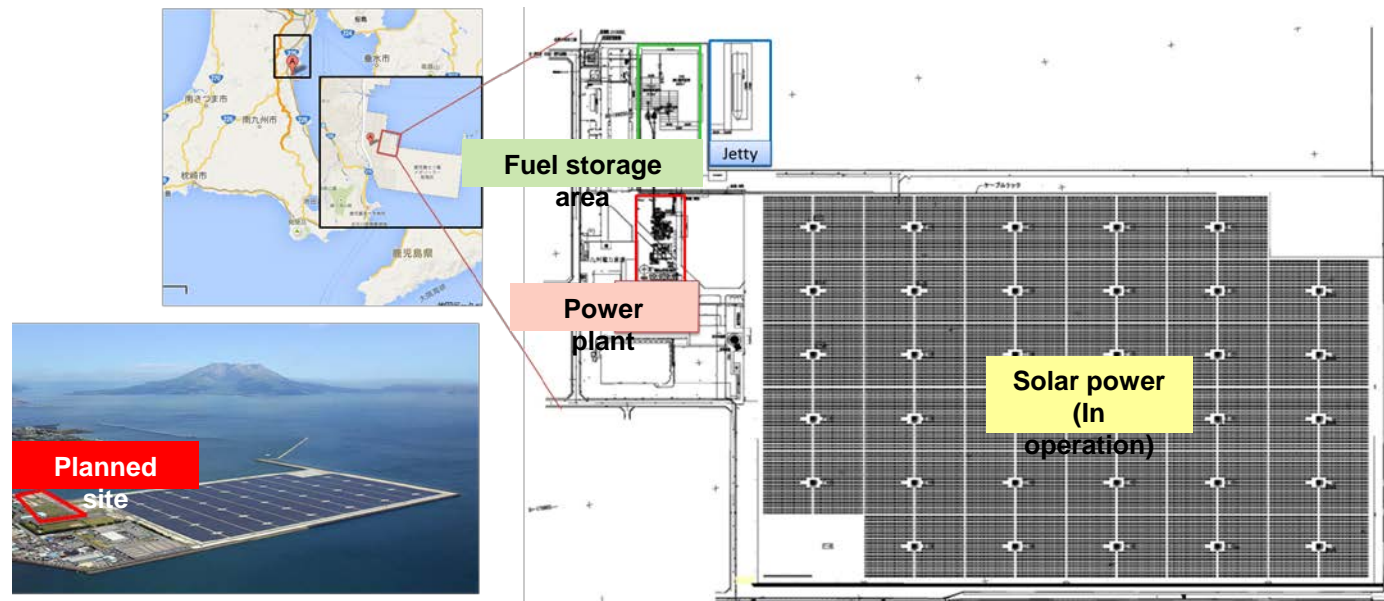
# Circulating Fluidized Bed Boiler (CFB)

## On-going CFB project for FIT business

### Establishment of company to operate biomass power plant

IHI has partnered with eight investment-partner companies to establish Nanatsujima Biomass Power Company, a company that will operate the largest woody biomass power plant in Kagoshima, Japan. Commercial operation will be started on November, 2018.

Through its involvement in the operation of the power plant that uses a feed-in tariff, IHI aims to expand into a life cycle business that includes operation and maintenance.



# Circulating Fluidized Bed Boiler (CFB)

## Overview of Nanatsujima biomass Power Plant

### ■ Specification

- ✓ Generator Output : 49 MW(Gross)
- ✓ Boiler Type : CFB with external heat exchanger
- ✓ Boiler Capacity : 175 t/h
- ✓ Steam conditions : 10.3MPa, 538°C (Turbine inlet)



### ■ Fuels

- ✓ Palm Kernel Shell (PKS) : 100% firing (Imported)
- ✓ Woody pellet : ~50% firing (Imported)
- ✓ Woody chip : ~ 5% firing (Domestic thinned wood)



PKS



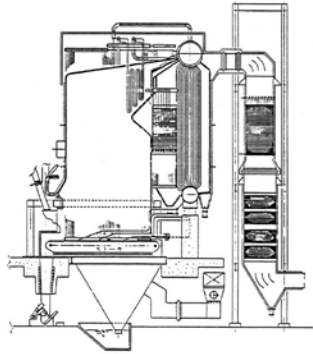
Woody pellet



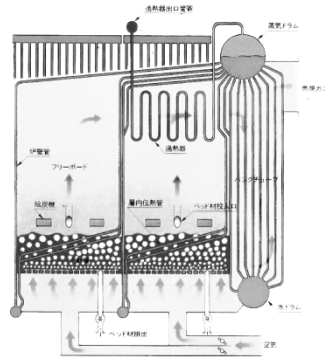
Woody chip

# Biomass fired combustion and gasification technologies

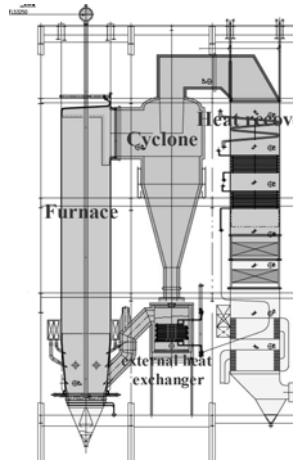
## Combustion



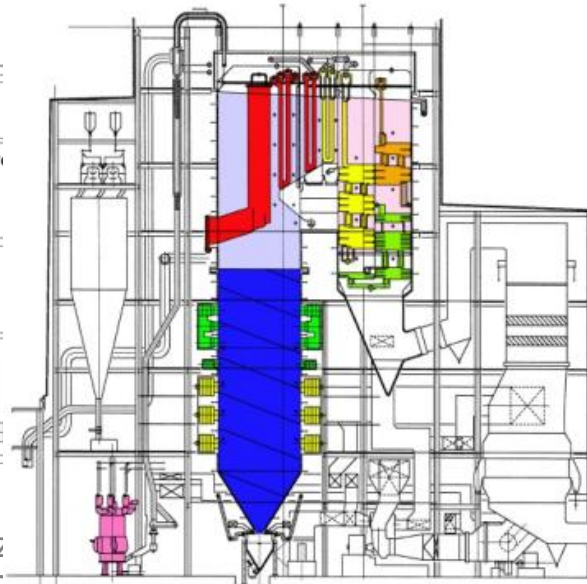
Stocker Boiler



Fluidized Bubbling Bed Boiler (FBB)



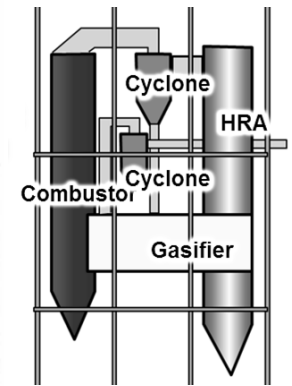
Circulating Fluidized Bed Boiler (CFBB)



**PULVERIZED COAL FIRED BOILER (PCFB)**

With co-combustion of biomass

## Gasification



Twin IHI Gasifier (TIGAR®)

## IHI's experience in biomass



Woody chip



Woody pellet

## Co-combustion ratio of biomass

30%

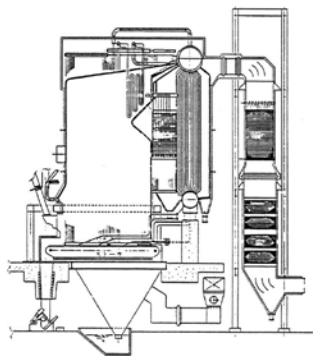
(Woody pellet)

In the commercial unit

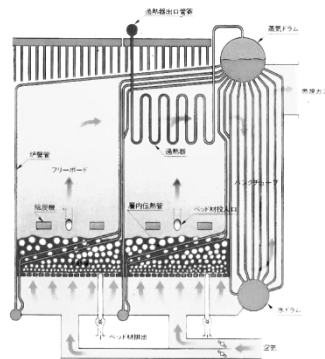


# Biomass fired combustion and gasification technologies

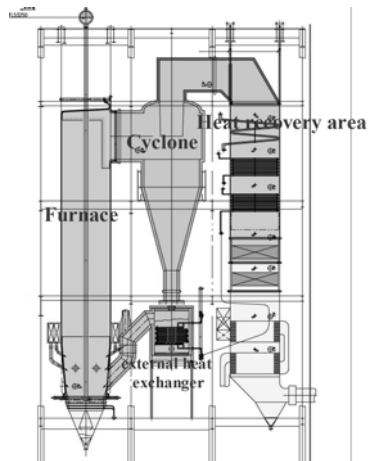
## Combustion



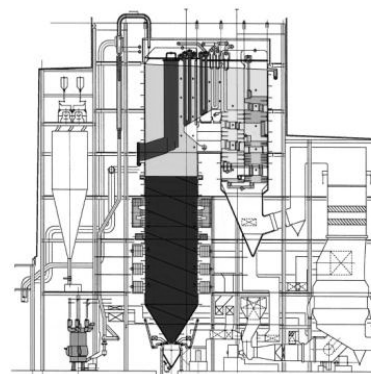
Stocker Boiler



Fluidized Bubbling Bed Boiler (FBB)

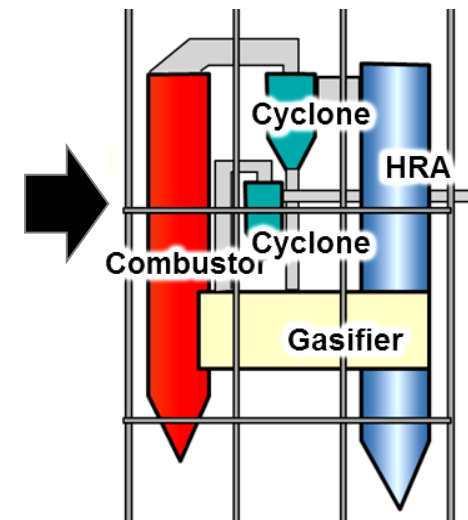


Circulating Fluidized Bed Boiler (CFB)



Pulverized Coal Fired Boiler (PCFB)

## Gasification



**TWIN IHI GASIFIER (TIGAR®)**

## IHI's experience in biomass



Woody chip



Woody pellet



Bark pellet

## Co-gasification ratio of biomass

100% (Woody biomass)

**In the pilot plant**

100% (Woody biomass)






**In the prototype plant**



# Twin IHI Gasifier (TIGAR®)

TIGAR® development process needs numerous facilities. In order to commercialize, each test plant from Lab to Prototype scale serves different purposes.

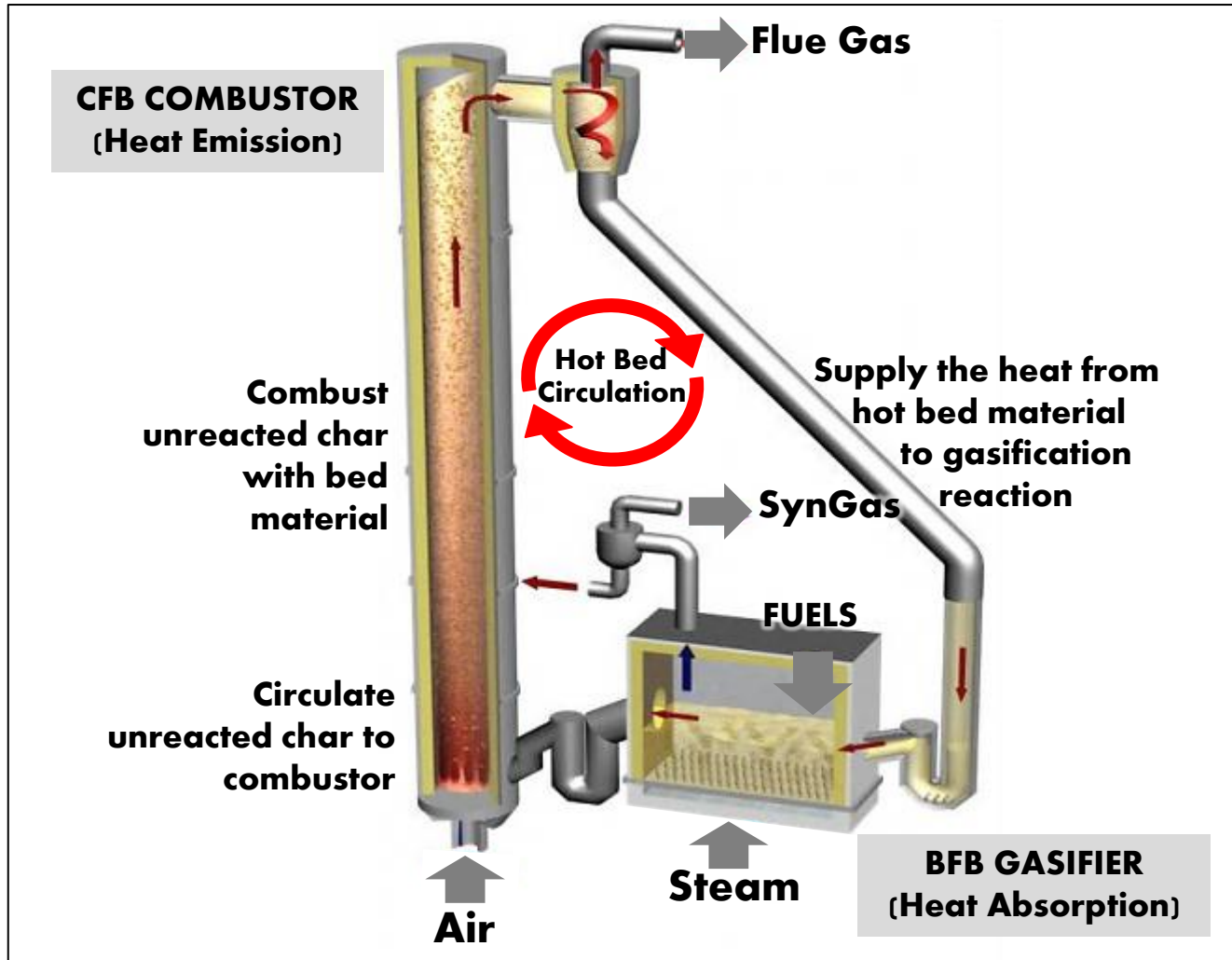
At Present  
↓

Lab Scale Testing	Bench Scale Testing	Pilot Plant Testing	Prototype Plant Testing	Commercialized Scale
<b>Batch</b>	<b>0.1T/D</b>	<b>6T/D</b>	<b>50T/D</b>	<b>300~1000T/D</b>
				
Tests of basic reaction rate @IHI Yokohama	Tests of gasification performance @IHI Yokohama	Tests of continuous operation @IHI Yokohama  <b>More than 2267 hours</b> Total operation time	Tests of overall process long operation performance @PTIGI Indonesia  <b>4780 hours of total operation and 1000 hours continuous lignite operation achieved !</b>	TIGAR × 4units (1 reserve) Coal feed : 3000 T/D (NH <sub>3</sub> : 1000 T/D)



# Twin IHI Gasifier (TIGAR®)

## ■ Principle of TIGAR



3D Model

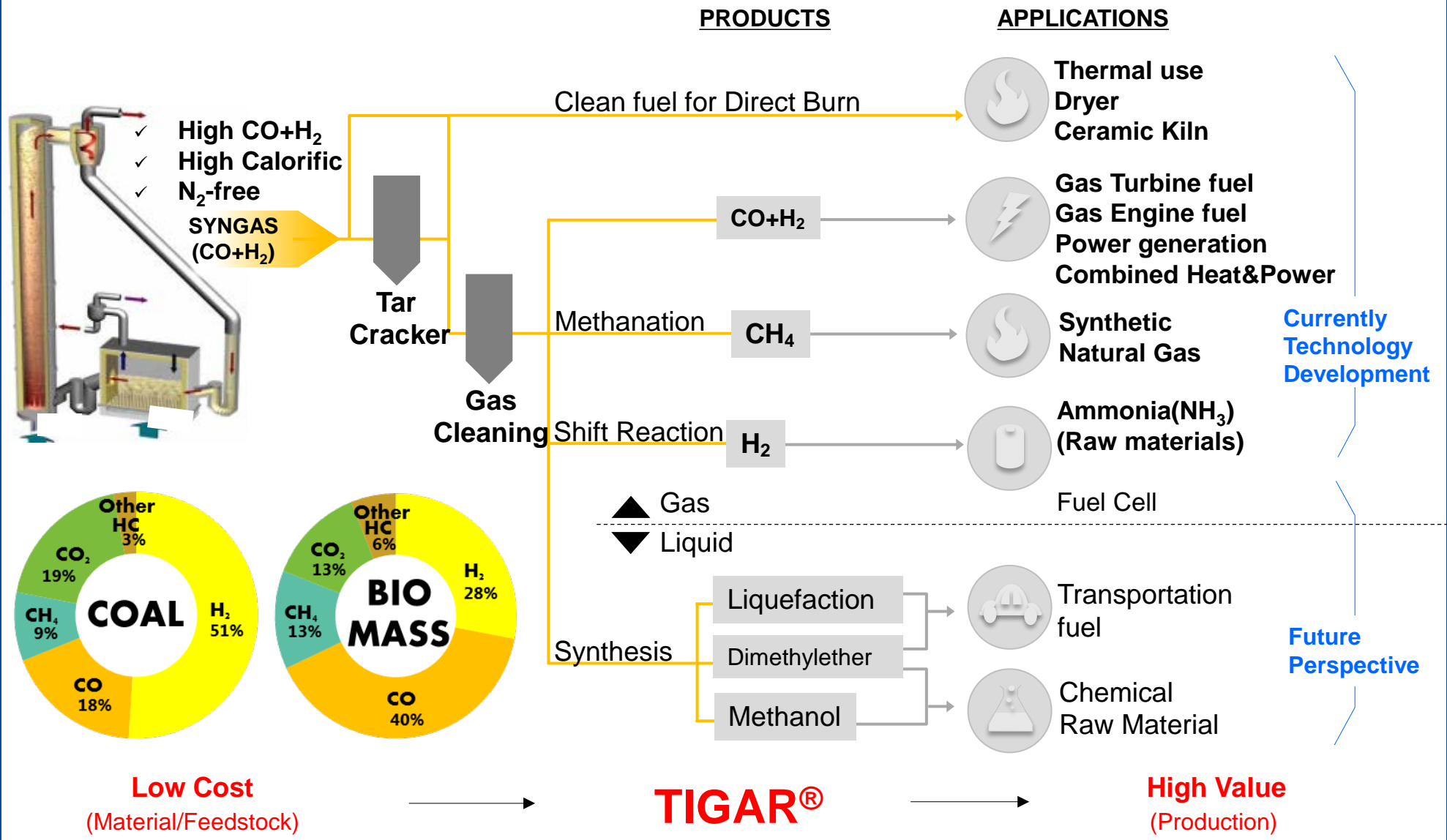


### OPERATION CONDITION

- ✓ Atmospheric pressure
- ✓ Low temperature

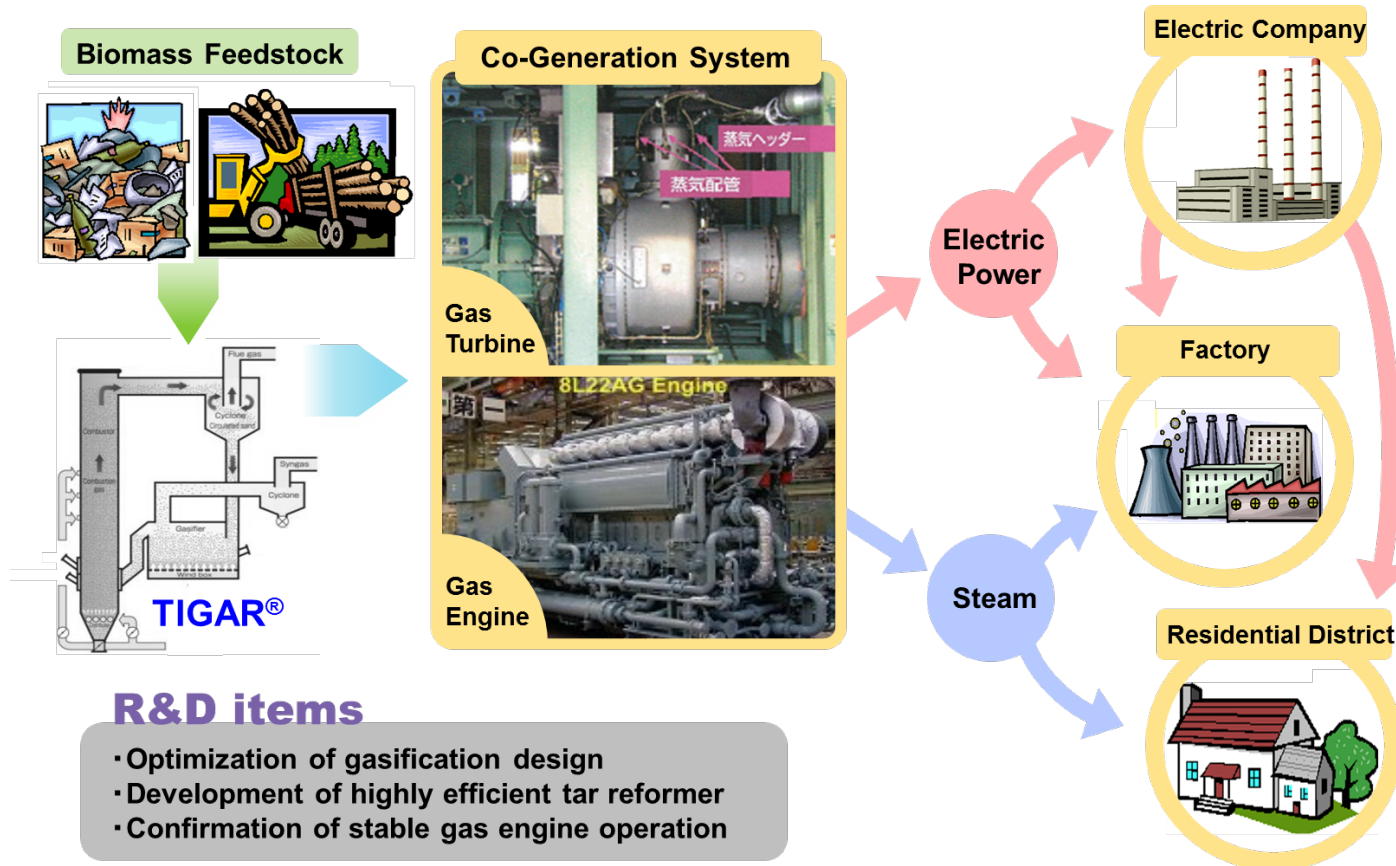
IHI

# Twin IHI Gasifier (TIGAR®)



# Research & Development – 6TPD Twin IHI Gasifier (TIGAR®)

## ■ CHP: Combined Heat and Power Plant



In the 6tpd pilot plant, 30kW power generation from biomass gasification using gas engine has successfully carried out.



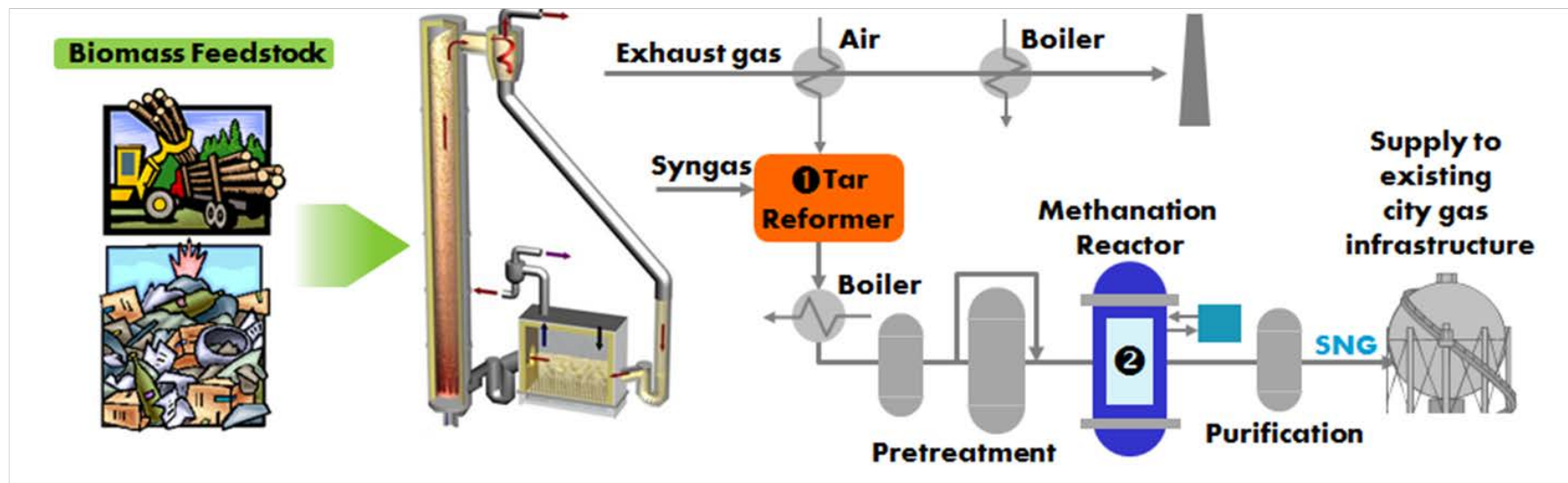
# Research & Development – 6TPD Twin IHI Gasifier (TIGAR®)

## ■ SNG: Synthetic Natural Gas

The clean syngas from TIGAR®, after gas cleaning unit as tar reformer, could be utilized to produce synthetic natural gas (SNG) by methanation process and supply the SNG to existing city gas infrastructure.

### R&D ITEMS

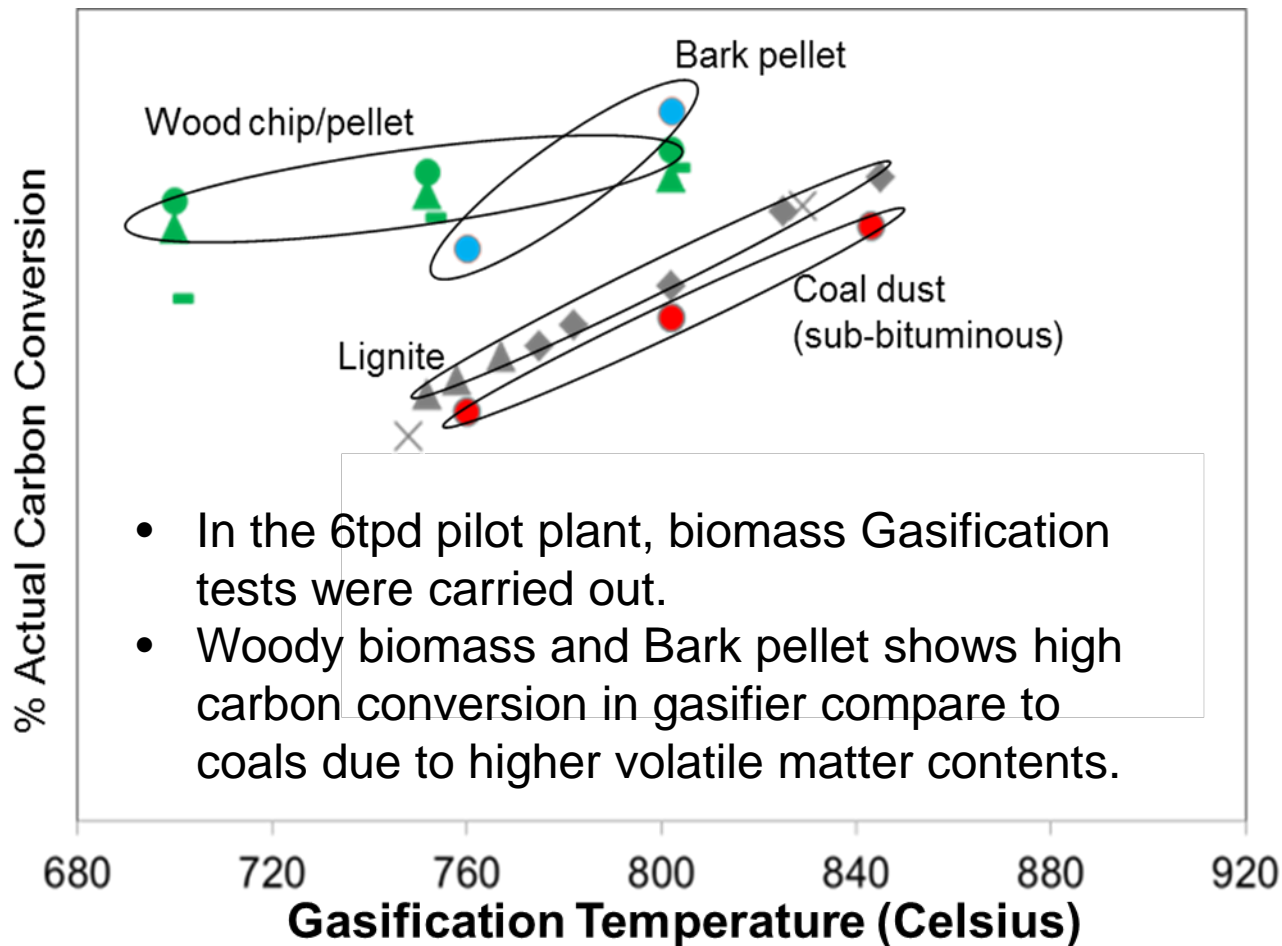
- ① Development of highly effective tar reformer
- ② Development of methanation process for syngas



In the 6tpd pilot plant, SNG production from biomass gasification has successfully carried out.

# Research & Development – 6TPD Twin IHI Gasifier (TIGAR®)

## ■ %Actual Carbon conversion of each kind of biomass compare with coals



- In the 6tpd pilot plant, biomass Gasification tests were carried out.
- Woody biomass and Bark pellet shows high carbon conversion in gasifier compare to coals due to higher volatile matter contents.



**6T/D Pilot Plant TIGAR®  
Yokohama Japan**

\*Results of lab scale experiments and simulate to 6TPD pilot plant

# Research & Development – 50TPD Twin IHI Gasifier (TIGAR®)

## ■ Demonstration of prototype TIGAR®

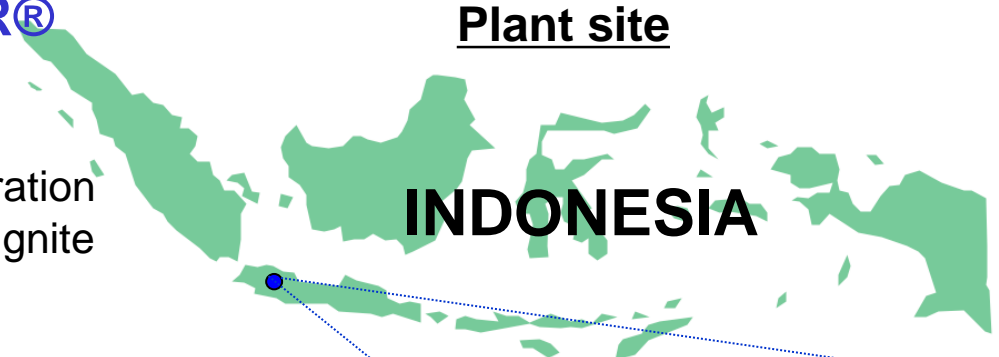
### Purpose of 50T/D Prototype TIGAR®

- ✓ Check the maintenance durability in long operation (Total 4,780 hr operation) using Indonesia lignite and biomass.
- ✓ Confirmation of TIGAR performance and reliability, and reflect in commercial plant engineering.
- ✓ Demonstration of TIGAR gasification technology for future clients.

### 50T/D Plant specification

Coal feed rate	50T/D (as received, 43% moisture)
Syngas output	1,800m <sup>3</sup> N/h-dry
Steam generation	4.5t/h (2.0MPaG, 513deg.C)
Site area	100m × 80m

### Plant site



**INDONESIA**



# Research & Development – 50TPD Twin IHI Gasifier (TIGAR®)

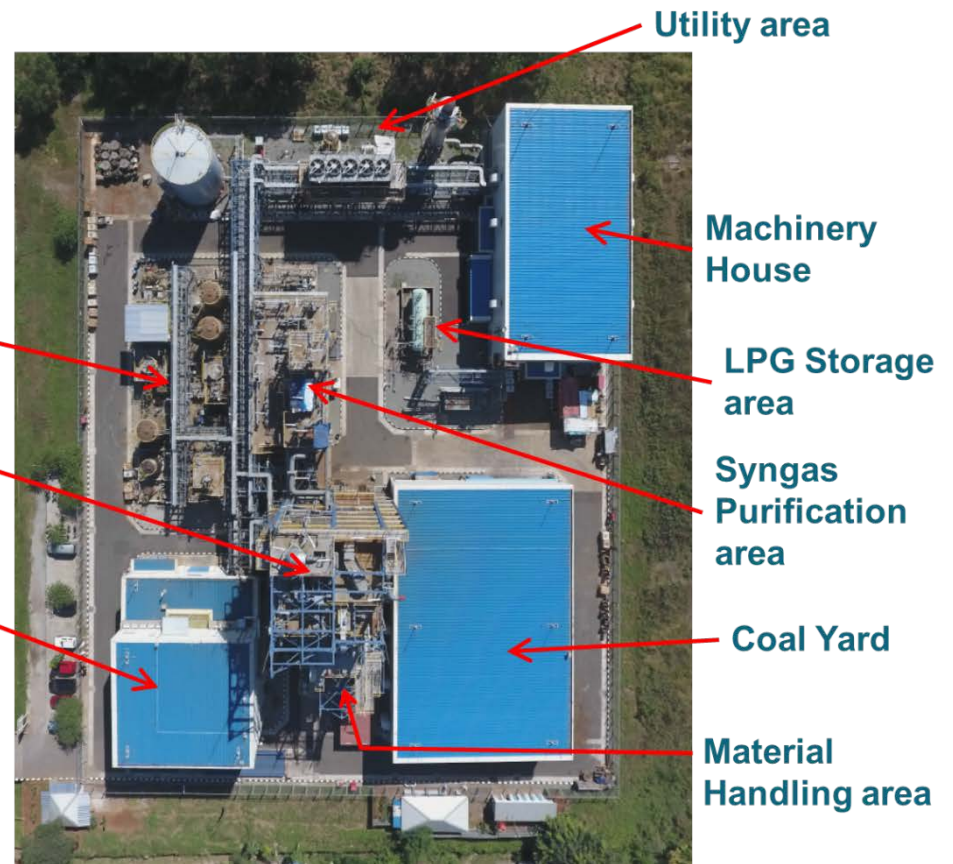
## ■ Demonstration of prototype TIGAR®



Waste Water Treatment area

Gasifier(TIGAR®)

Control Building

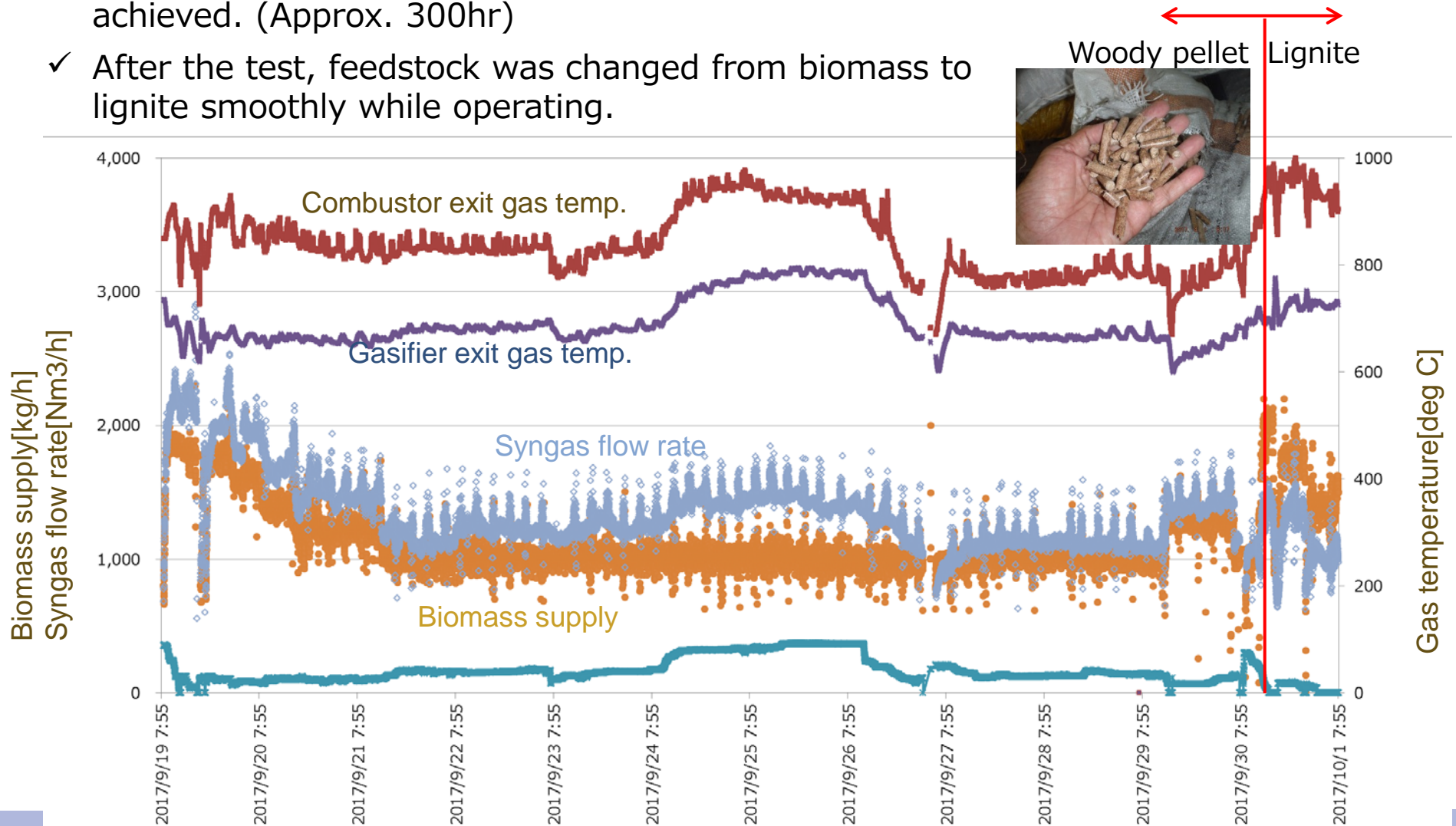


IHI

# Research & Development – 50TPD Twin IHI Gasifier (TIGAR®)

## □ Biomass gasification test

- ✓ Stable gasification of 100% biomass was successfully achieved. (Approx. 300hr)
- ✓ After the test, feedstock was changed from biomass to lignite smoothly while operating.



# CHAPTER 4

## Conclusion

# Conclusion

- IHI has contributed to develop technologies for the reduction of CO<sub>2</sub> with biomass utilization.
- Various kinds of biomass can be utilized effectively by IHI's suitable combustion and gasification technologies at its optimum in both economic and technical.
- IHI is pursuing the realization of the further innovative and advanced technologies in the clean energy for the sustainable society future.

**Thank you for your kind attention !**

**ご清聴を感謝します！**

**IHI**

**Realize your dreams**

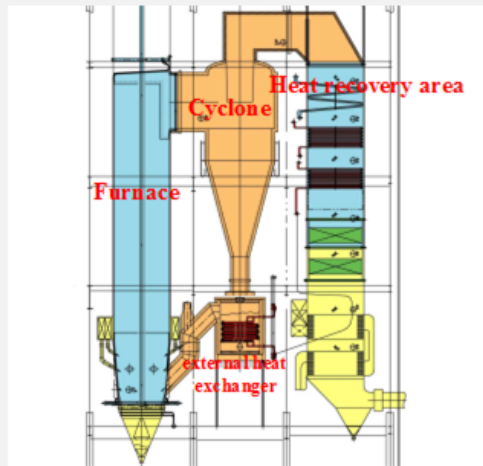


# TIGAR<sup>®</sup> FEATURES

## PROVEN DESIGN & MANUFACTURING

### CFB EXPERIENCE

- Rich and long in CFB Experience through Boiler manufacturing.
- 1200 TPD capacity of CFB commercialized since 1992
- 100-1000 TPD/unit are available



### HIGH QUALITY MANUFACTURING

- IHI owns factories in Japan (Aioi) & Indonesia (PTCF)

## MULTI-FEEDSTOCK

- Many kinds of feedstock have been approved.
- Lignite, sub-bituminous, biomass
- Coarsely size are available with no pre-treatment required
- Feedstock changeable during non-stop operation



## LOW CAPEX & OPEX

### CONVENTIONAL EQUIPMENTS

- Conventional feeding system
- Easy spare parts ordering & consumables

## EASY O&M

### OPERATION UNDER ATMOSPHERIC PRESSURE & LOWER TEMPERATURE (800-900°C)

- No high grade material required
- Simple feeding of coal & biomass without special feeding system
- No N<sub>2</sub> feeder required results in no N<sub>2</sub> contamination in syngas
- Easy training & familiarization for operators

