



Drying and Torrefaction of Coal/Biomass by COMB Technology

The KIER, a global energy innovator, does its best in pursuing its mission to invent world-class energy technologies based on open innovation, life-cycle research quality assurance, participatory and open communication. Therefore the KIER will become the best energy technology R&D institute in the world, contributing to the creation of wealth and improvement of quality of life for the people.

13th July, 2017

Sihyun LEE

Korea Institute of Energy Research



Diversity of Solid Fuels

Low Rank Coal	USA	Germany	Australia		Indonesia	
	Fort Union	Rhine	Norwell	Loy Yang	Wara	Milia
Moisture*	37.2	55.7	60.1	61	32	35
Volatile**	44.6	53.1	49.4	51.9	36	38
Ash*	6.2	2.1	1.3	0.5	2	3.3
HHV(kcal/kg)	4,200	2,270	2,533	2,630	4,800*	4,995*

Coal

- Limitation of high quality coal supply
- Huge reserves of low rank coal : high moisture content and spontaneous combustion

Biomass

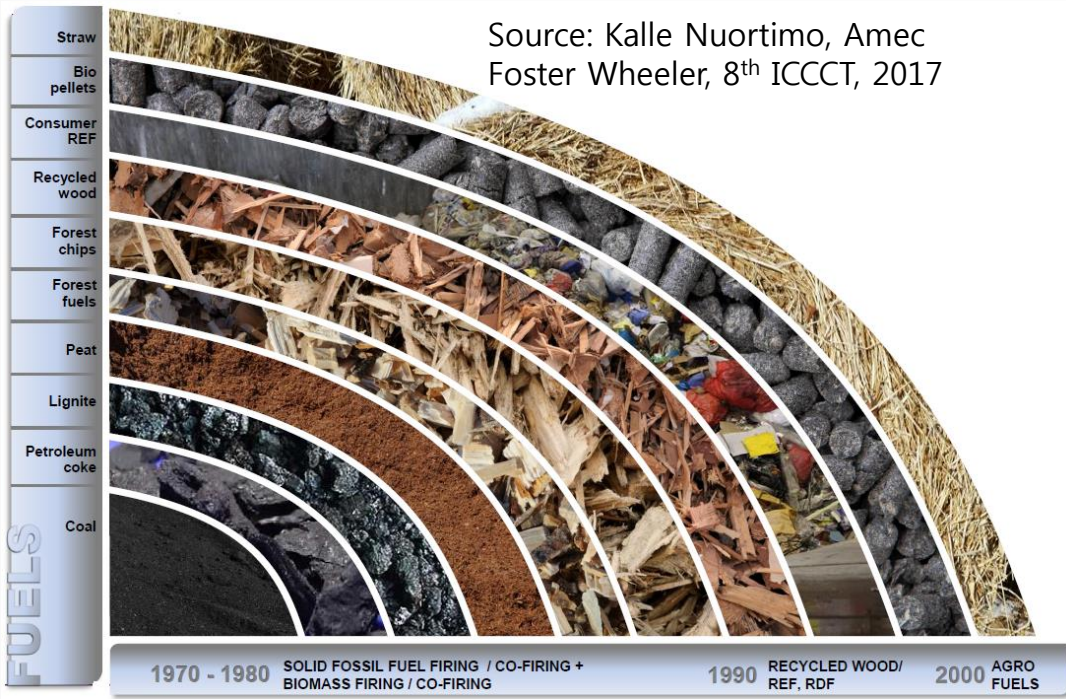
- Reducing the CO2
- Biomass market changed to global market
- Large scale power generation of biomass alone and co-firing
- Increasing interest to applying agricultural biomass & waste

Increasing use of low rank coal & biomass

- Low efficiency for power generation due to low calorific value and high moisture

Need energy efficient upgrading technology (Drying & torrefaction)

Source: Kalle Nuortimo, Amec Foster Wheeler, 8th ICCCT, 2017



Low Rank Coal Drying Technologies



DRYLIG : Project overview

Project data

- Duration: July 2014 – June 2017
- Budget: € 2,207,633
- www.drylig.eu
- Funded by Research Fund for Coal and Steel, Grant agreement: RFCR-CT-2014-00009



Main objective:

- Adoption of pre-dried lignite utilization towards increased flexibility, improved efficiency and environmental and economic performance



Biomass Torrefaction Technologies

EU project to develop torrefaction technology

project brief

- Collaborative project: SECTOR
- Project start: 01.01.2012
- Finalisation: 30.06.2015
- Total budget: € 10 Million
- Participants: 21 from 9 EU-countries
- Coordinator: DBFZ, Germany



Torrefaction Technologies within SECTOR

ECN: Moving bed reactor



- Characteristics:**
- Moving bed torrefaction
 - Direct heating using recycled torrefaction gas
 - Recycle boosting of torgas to compensate for pressure drop
 - Torgas utilization for internal energy demand

CENER, Umeå University: Rotary drum reactor

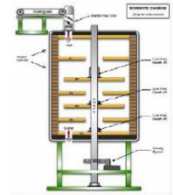
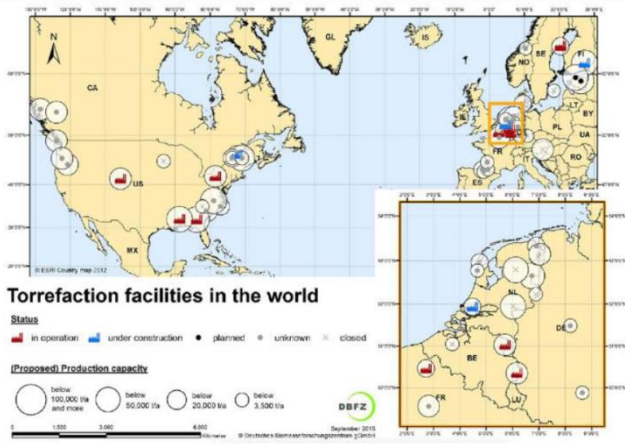


- Characteristics:**
- Proven technology
 - Indirectly heated with flue gas
 - Accepts larger particles

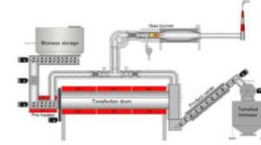
Topell: Torbed reactor (full scale demonstration)



- Characteristics:**
- Cylindrical reactor
 - Hot rotating process gas keeps raw material in motion (creates „bed“ that is formed by biomass itself)
 - Quick heat-to-mass transfer
 - No moving parts



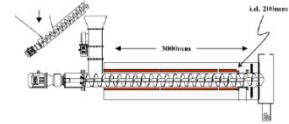
Multiple hearth furnace



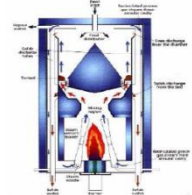
Rotary drum reactor



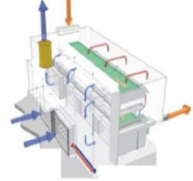
Moving bed reactor



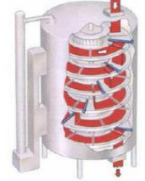
Screw conveyor reactor



Torbed reactor



Oscillating belt reactor



TurboDryer

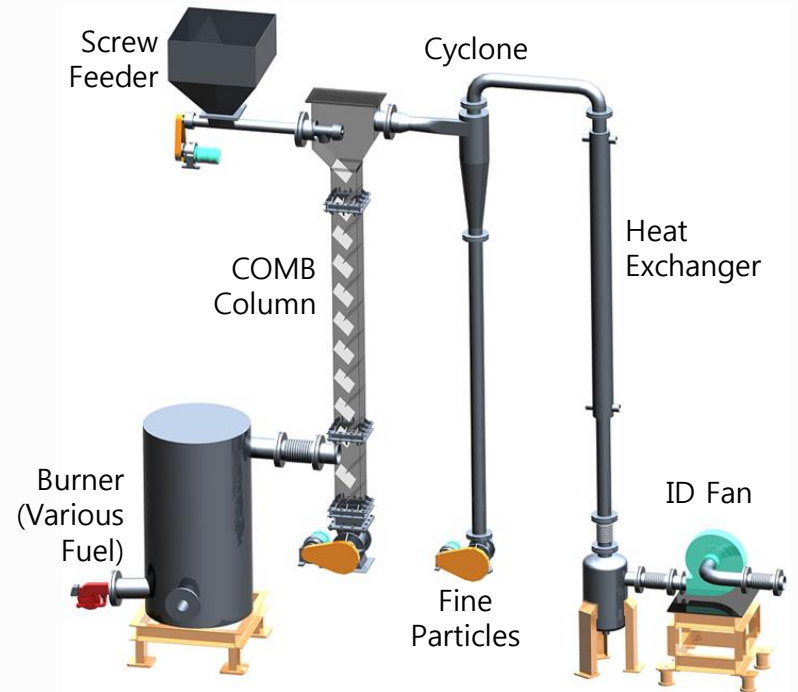
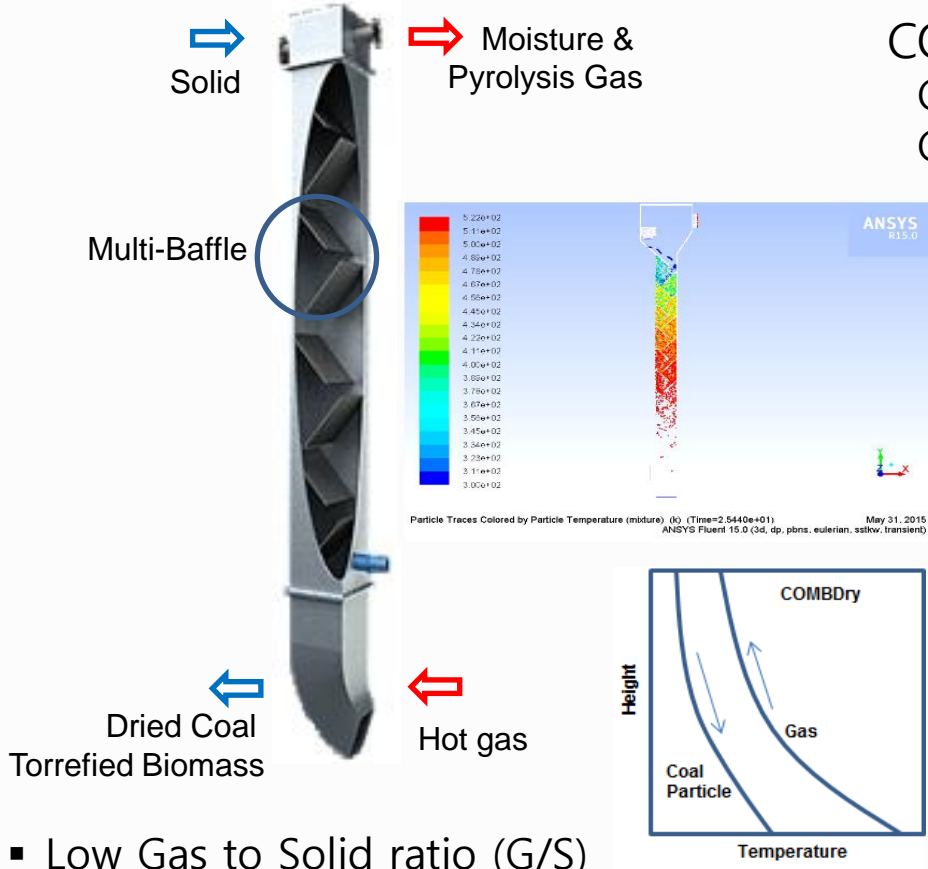


Microwave reactor



KIER: COMB Tech.

COMB: Counter flow Multi-Baffle
 COMBDry™ : for drying
 COMBPy™ : for pyrolysis (torrefaction)



- Low Gas to Solid ratio (G/S)
- Short residence time (~5min)
- Constant temperature difference (driving force) along the column
- Simple, Flexible & Movable

Coal Drying : COMBDry™



Drying High Moisture Low Rank Coal

Purpose

- Low rank coal upgrading with drying and stabilizing, securing coal for energy security

Progress and Plan

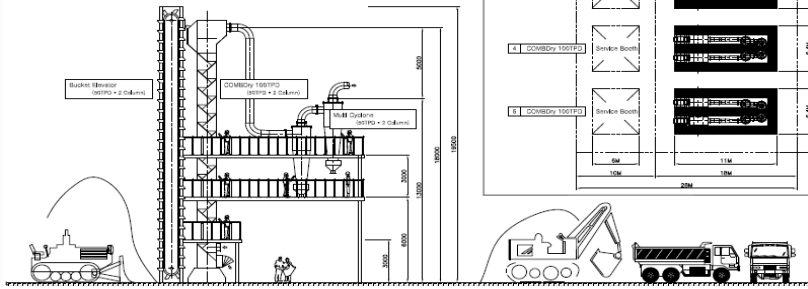
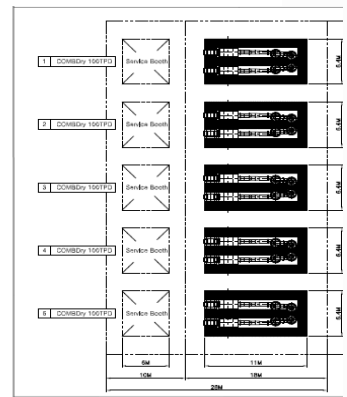
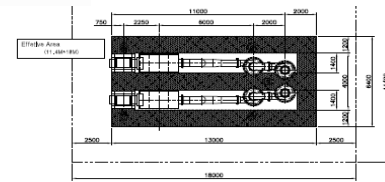
- Collaboration network built to jointly develop low rank coal upgrading technology at Indonesia, China, and Australia. Demonstration site selection on a coal mine and power plant underway in each country

Achievement and Future Prospects

- Launching 2017 International Cooperation Project with Australia (Monash University) to develop Victorian Brown Coal drying



20kg/hr, 50kg/hr BSU COMB facility



Commercial design model for Counter flow Multi-Baffle (COMB) facility



Biomass Torrefaction : COMBPy™

White pellet & Black pellet from EFB & OPT

Purpose

Upgrading palm residues

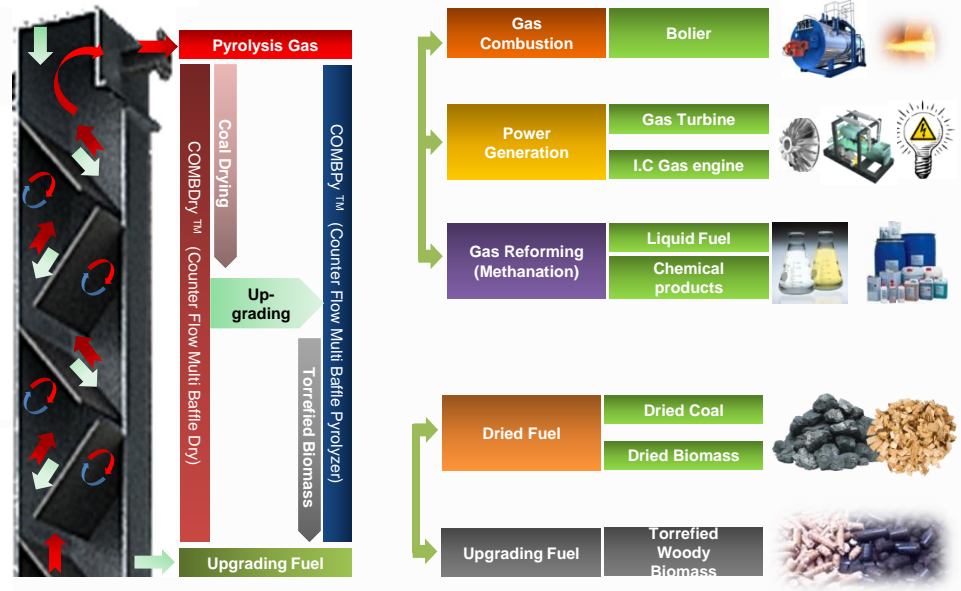
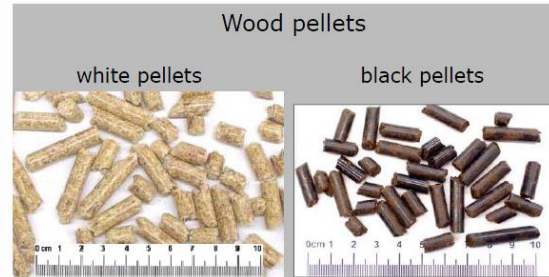
- Indonesia palm residues upgrading and utilization in combustion and gasification for CHP (Combined Heat & Power)

Progress and Plan

- Demonstration and site selection on a POM (Palm Oil Mill) underway in Lampung,
- Indonesia Discussion linkage program with Indonesia for distributed power generation project

Achievement and Future Prospects

- Produce PDP (Process Design Package) for industrial demonstration COMBPy/CHP plant that will be installed in 2018

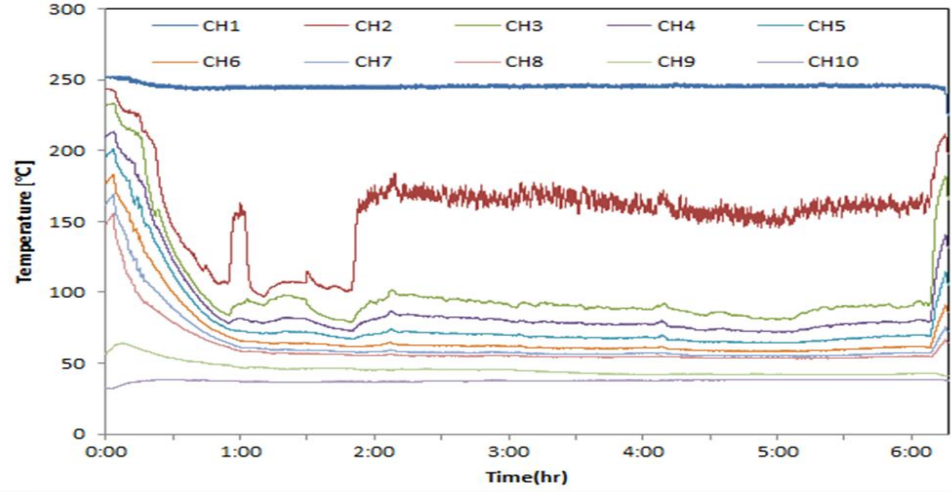


Concept of COMB. Tech. for drying and torrefaction



Results : Coal Drying

Temperature profile along the column



Burner outlet (column inlet) : 250°C
 Average bed temperature : 80°C
 Column outlet : 50°C

Chinese Inner Mongolia Lignite

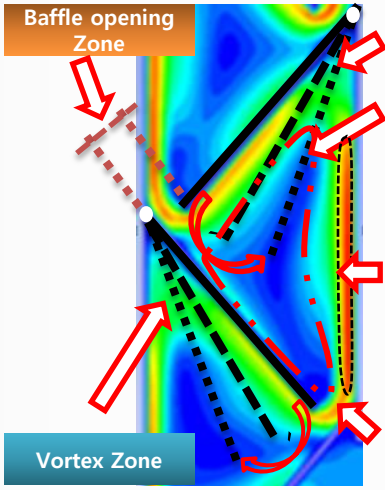
Proximate analysis (wt%, ar)	Raw coal	Dried Coal
Moisture	36.0	11.2
Ash	3.6	5.4
Volatile matter	32.3	41.3
Fixed Carbon	28.0	42.1
Calorific value (HHV, kcal/kg, ar)	4,230	5,760
Ultimate analysis (wt% adb)		
Carbon	44.3	60.6
Hydrogen	6.77	5.03
Nitrogen	1.85	1.93
Sulfur	0.04	0.06
Oxygen	43.3	29.38

Imported coal to EWP	Proximate Analysis (% , wt)				Calorific Value (kcal/kg)
	M	VM	FC	A	
Raw Coal	24.98	35.18	36.99	2.85	4,180
COMBDry_150	11.42	41.04	42.16	5.39	5,640
COMBDry_200	10.49	41.39	43.48	4.64	5,742
COMBDry_250	7.2	42.6	45.04	5.16	6,033



Results : Biomass Torrefaction

Malaysia Biomass (Sawdust)	Proximate Analysis (% wt)				Calorific Value (kcal/kg)
	M	VM	FC	A	
Raw Biomass	19.04	64.31	16.06	0.59	3,892
COMBPy_250	2.65	77.55	19.25	0.65	4,569
COMBPy_280	1.69	77.18	20.35	0.78	4,699
COMBPy_300	0.92	76.03	22.33	0.93	5,015
COMBPy_320	0.7	70.62	27.62	1.07	5,088
COMBPy_340	0.6	69.02	29,25	1.13	5,112



- Tilting Baffle**
- Fluidized Mix Zone**
- Core Zone**
- Knock-out Zone**



COMBPy_250 COMBPy_280 COMBPy_300 COMBPy_320 COMBPy_340

Variable Tilting Baffle: Tilt angle adjustment in response to the shape and size of the raw material
 Fluidized Mix Zone: Control by flow rate of the particles & the heat flow in response to the drag coefficient
 Core Diffusion Zone: Floating diffusion flow corresponding to the drag coefficient of the particles
 Knock out Zone: Discharge of the particle due to the particle flow velocity drop from the mixing section
 Opening Zone: Control of the opening considering the size and density of the particles
 Vortex Zone: Vortex generation section for mixing of fluidizing particles

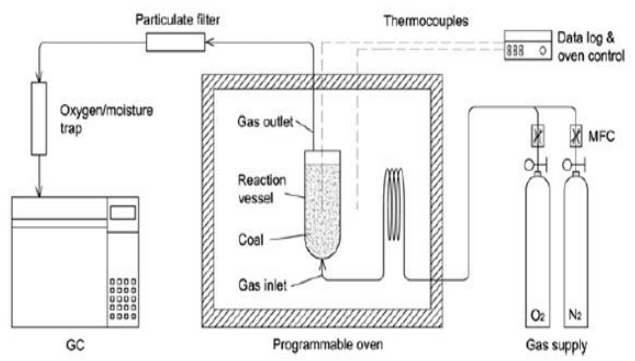
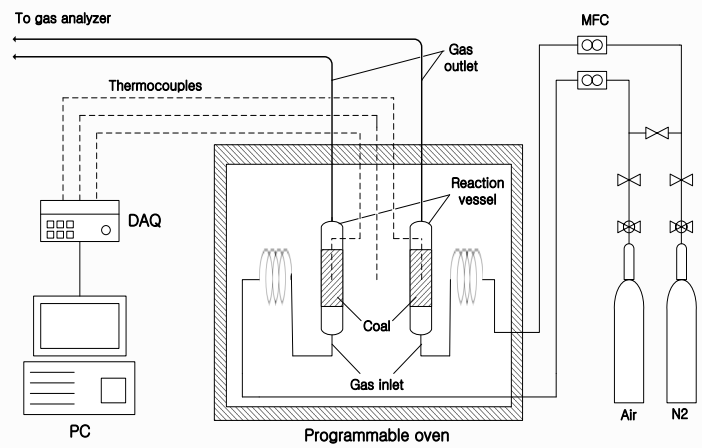
Optimization for various types of biomass with different morphology



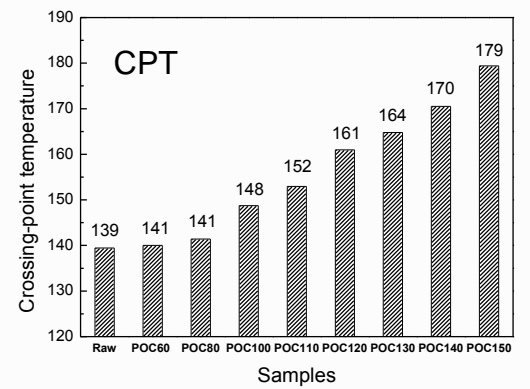
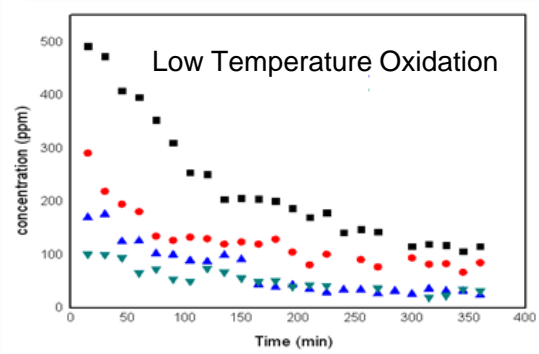
Activities of KIER's Clean Fuel Lab.

- Proximate/Ulimate/Calorific Value
- TGA/DTA (thermal properties)
- Ash analysis, ash behavior
- Functional Groups (FTIR) analysis
- CPT (Cross Point Temperature)/LTO (Low Temperature Oxidation) measurement for spontaneous combustion
- Water resistance/water re-adsorption after drying
- Briquetting & Strength measurement (drop/tumbling)

CPT Measurement Apparatus



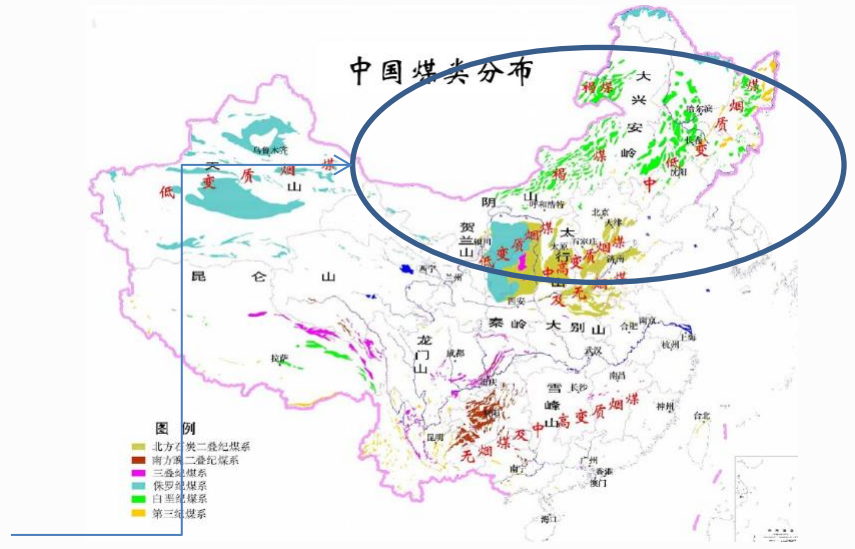
Apparatus for Low Temperature Oxidation



Cooperation China



50kg/h COMB BSU (China, HIT, '15)
Target coal: High moisture Inner Mongolia Lignite



Product Rotary Valve



Dust Rotary Valve



Temp measure (11 Points)



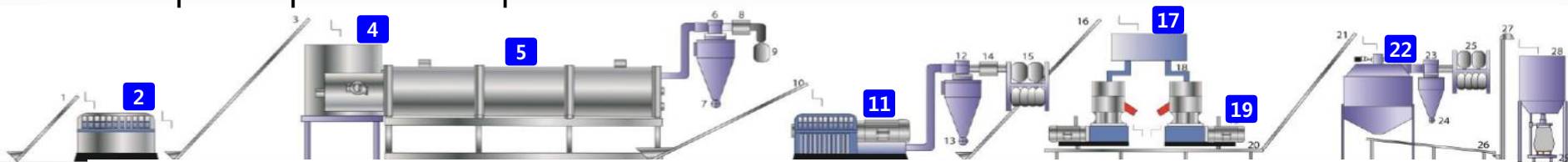
Pres. measure (5 Points)

HIT conclusion:
The flue gas temperature of boiler was about 200°C in actual power plant, the experimental condition in this research was in accordance with the **actual situation, so the results were applicable to technical upgrading in actual power plant.**

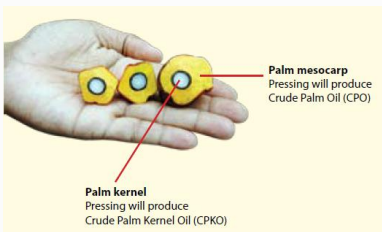
HIT: Harbin Institute of Technology



Wood pellet production process



1	Chain conveyor	2	EFB Shredder	3	Belt conveyor	4	2 in 1 Biomass burner
5	Rotary dryer	6	Cyclone system	7	Air lock	8	Blower
9	Dust collector	10	Belt conveyor	11	Grinder	12	Cyclone system
13	Air lock	14	Blower	15	Dust collector	16	Belt conveyor
17	Mixer tank	18	In feed screw conveyor	19	Flat die pelletizer	20	Belt conveyor
21	Inclined belt conveyor	22	Cooling tower	23	Cyclone system	24	Air lock
25	Dust collector	26	Vibrating screener	27	Bucket elevator	28	Storage tank
29	Electronic weighing scale						



FFB (Fresh Fruit Bunch)



COMBDry : Drying to make palm pellet (20MJ/kg)
COMBPpy : Torrefaction to make black pellet (26MJ/kg)

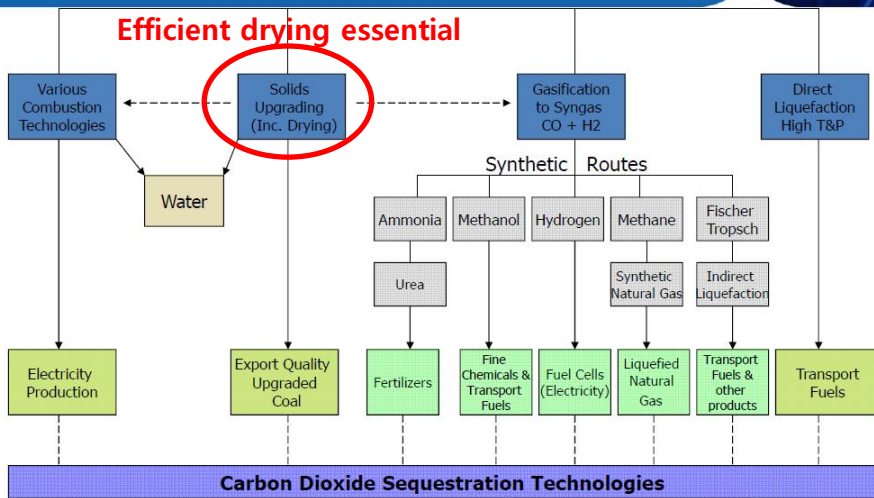
Indonesia partners

- ARDEMR: Agency of R&D for Energy and Mineral Resources
- tekMIRA
- Lampung University
- ITB: Institute of Technology Bandung

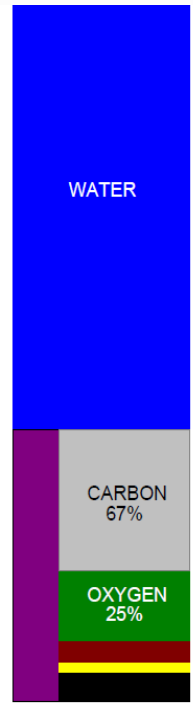


Cooperation Australia

Prospective Value-added Products from Victorian Brown Coal



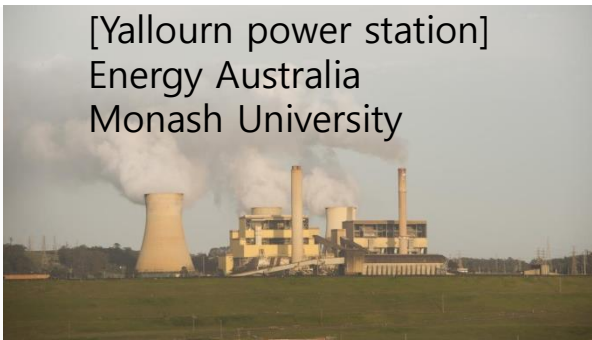
Source: Victoria state government



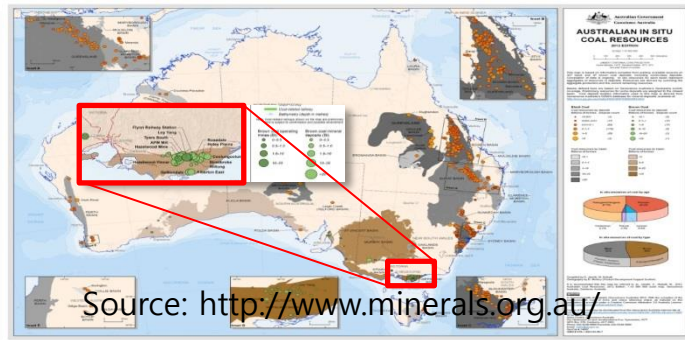
% weight moisture 60-70%

BCIA support project: Development of Biomass and Coal Drying Using COMBDry Technology (2017)

Hydrogen 5%
Sulphur & Nitrogen >1%
Ash ~2%



[Yallourn power station] Energy Australia Monash University



Source: <http://www.minerals.org.au/>

The proposed project involves tests at the power plant site to prove the drying capability of COMBDry



KIER developed COMB. Technology : Counter fLOW Multi Baffle Technology

- Coal drying and mild pyrolysis for coal stabilization (reducing self-heating propensity)
- Torrefaction of woody/herbaceous biomass to make black pellet (26MJ/kg)

Status

- 1ton/day (50kg/hr) BSU (Bench Scale Unit) operation in Korea
- International cooperation project
 - HIT (Harbin Institute of Technology), China : Inner Mongolia Coal Drying
 - Monash University, Australia : Victorian brown coal drying

Future Plan

- Demonstration at Australia for coal drying (power plant site, 2018)
- Demonstration at Indonesia for coal drying (mine mouth) and biomass torrefaction (POM site, 200kg/hr, 2019)

Thank you!



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