KIER

GLOBAL KIER TECHNOLOGIES

8th International Conference on Clean Coal Technologies, 8-12 May 2017, Cagliari, Italy

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.

9th May, 2017

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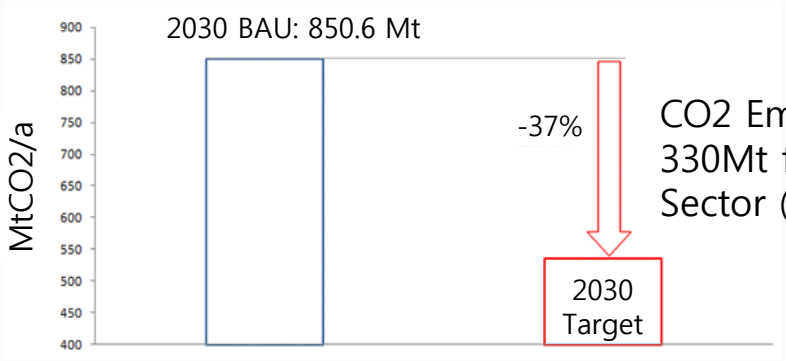
Clean Coal Strategies in Korea

- Adoption of high efficient power plants
  - A $15 billions is to be invested in PC power stations such as IGCC and USC 1000MW class
  - Coal performance, cost, and reliability demonstrations are required in advanced power technologies
- Improve efficiency of existing power plants
  - $1.2 billions is needed for Korean standard power stations of 500MW, 30 units
  - Retrofit existing plants with improved technology; target of 1~2% increased efficiency
- Fuel Switching
  - Fuel blends, coal upgrading strategies
  - Co-firing coal/biomass, Hybrid coal etc.
  - RPS raising up to 10% in 2022
- Carbon sequestration
  - CO2 capture and utilization(CCSU)

Source: C.H. Jeon, Pusan Clean Coal Center (2015)



CO2 Emission 330Mt from power Sector (2030)

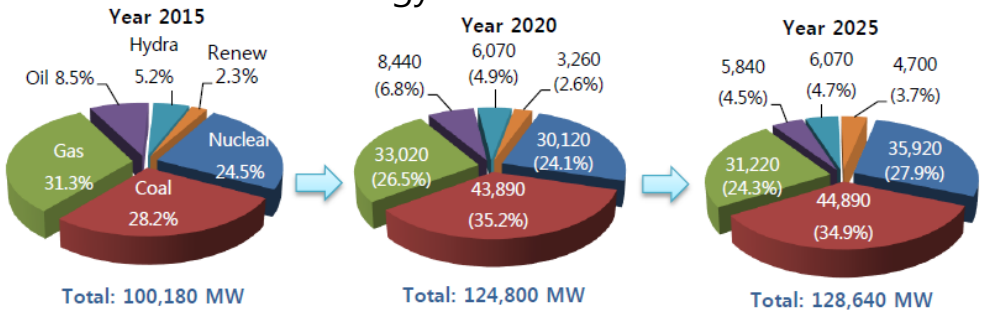
Target Reduction : 315Mt

CO2 Reduction Scenario : 37% (2030)

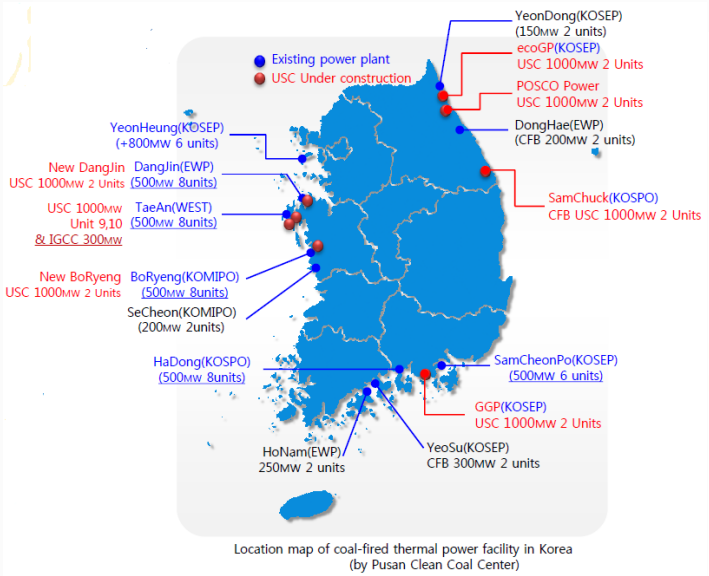
National Reduction : 25.7%
- HELE (High Efficiency Low Emission) Combustion System, USC
- Biomass Co-firing & Biomass Only Combustion Boiler

International Market Mechanism : 11.3%
- Complementary cooperation with ASEAN, China, Australia

Energy Mix in Korea



Korea's Boiler History up to USC

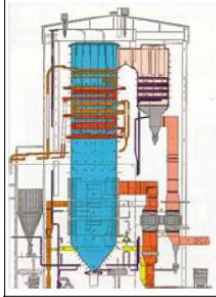
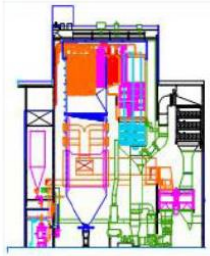
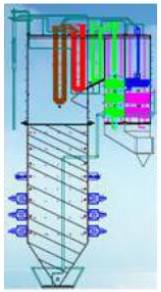
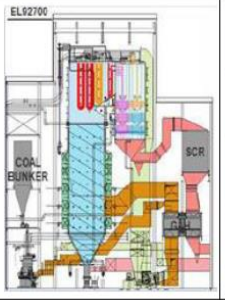
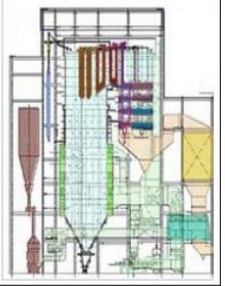
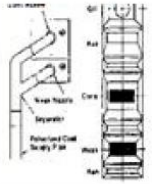
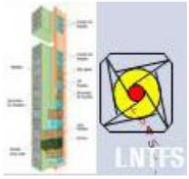
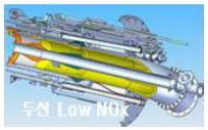


Location map of coal-fired thermal power facility in Korea
(by Pusan Clean Coal Center)

- Installed capacity : 26.15 GW
- No. of power plants : 56 units
  - Standard units : 500MW 30 units
- Power source % composition (2013)
  - 28.9% power facility capacity basis
  - 40.0% power generation basis

- GENCO : KOSEP, KOSPO, EWP, KOMIPO, WEST
- IPP : GGP, ecoGP, POSCO with USC 1000MW
- No. of New USC 1000MW : 14 units

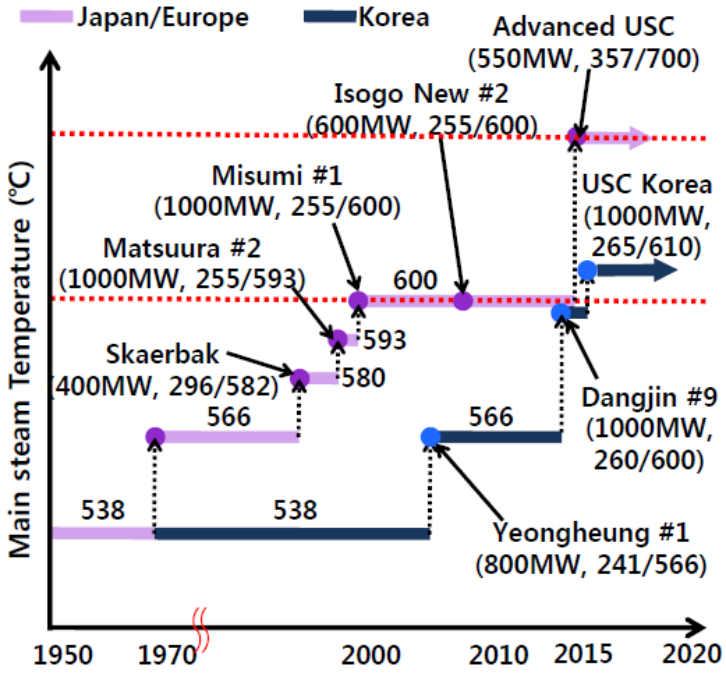
Pulverized Coal Fired Boiler

500 MW Standard type thermal power One pass / Corner	500MW New Standard Two pass / Corner	870W Yeongheung unit 5, 6 Two pass / Opposite	1000MW Shin BY unit 1, 2 Two pass /Opposite	1000MW DangJin Unit 9, 10 Two pass / Opposite
				
S. Temp. : 541 / 541 ℃ **S. Press.** : 255 / 40 kg/cm² **Design Coal** : 6080 kcal/kg	569 / 596 ℃ 255 / 55 kg/cm² 6080 kcal/kg	569 / 596 ℃ 252 / 45 kg/cm² 5300 kcal/kg	**613 / 624 ℃** **274 / 46 kg/cm²** **5600 kcal/kg**	**603 / 603 ℃** 265 / 46 kg/cm² 5626 kcal/kg
				

6 units over 100MW CFB boilers in Korea
1 units 500MW USC CFB Boiler in Korea

Source: C.H. Jeon, Pusan Clean Coal Center (2015)

Inconsistency



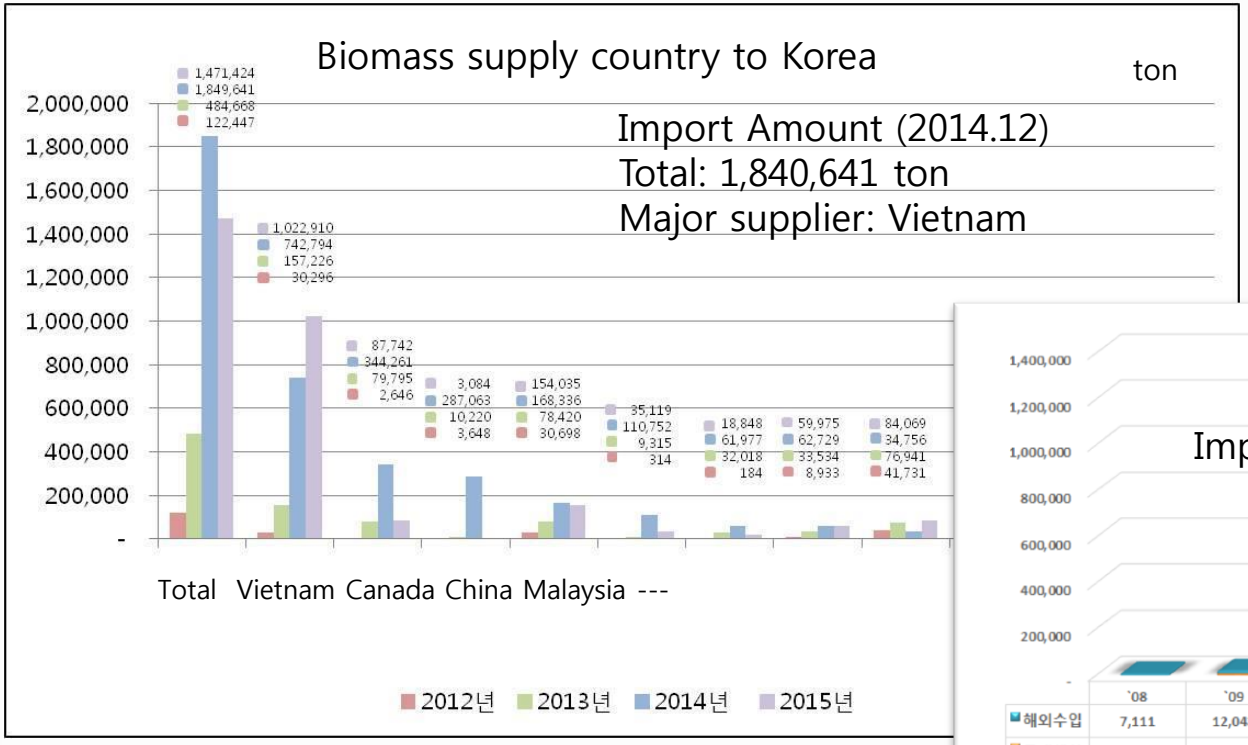
High Efficient USC Power Plant
(PC & CFB)

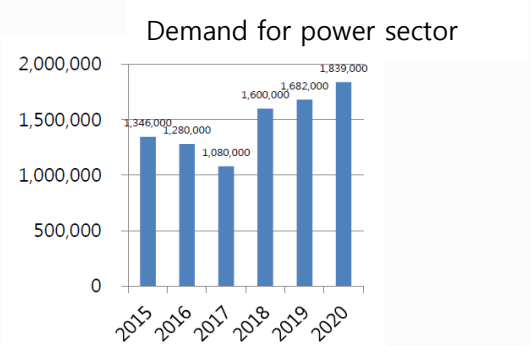
From Subcritical to Ultra Supercritical

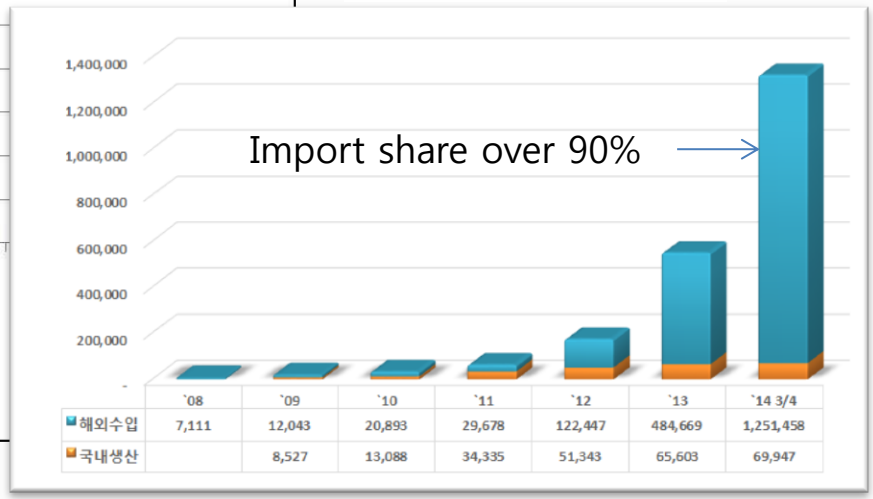
Facility Grade + Fuel Grade (Rank) = Efficiency not changed

From bituminous to sub-bituminous

Biomass Utilization in Korea







- Increasing amount of biomass become policy issue in Korea
  - REC (Renewable Energy Certificate) adjustment
  - Make upper limit for import
  - Quality control

Source: K.S. Han, Chungbuk National University (2016)

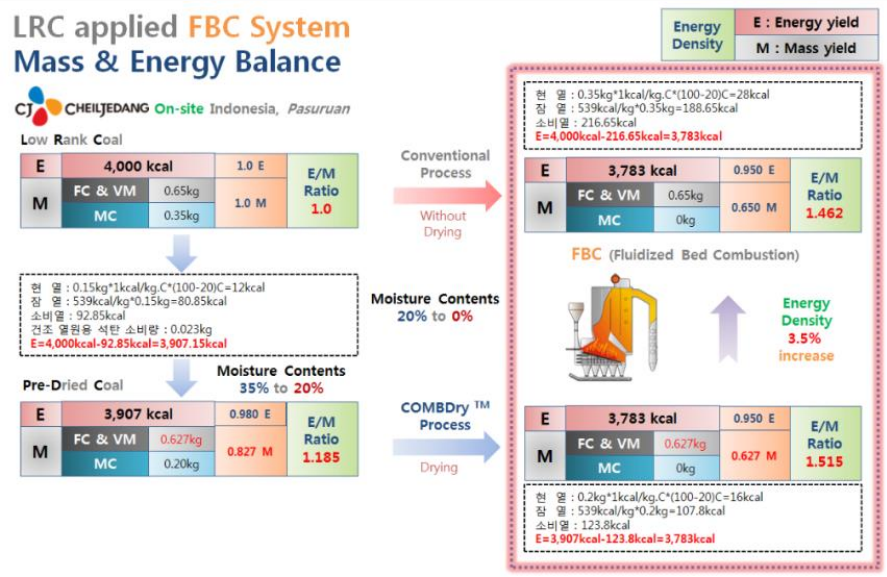
Solution is.. : Upgrading (Drying & Torrefaction)

Value Added ?

Vaporization in boiler (no pre-drying)

vs.

Pre-drying using waste heat



Operational Efficiency !

Case Study:

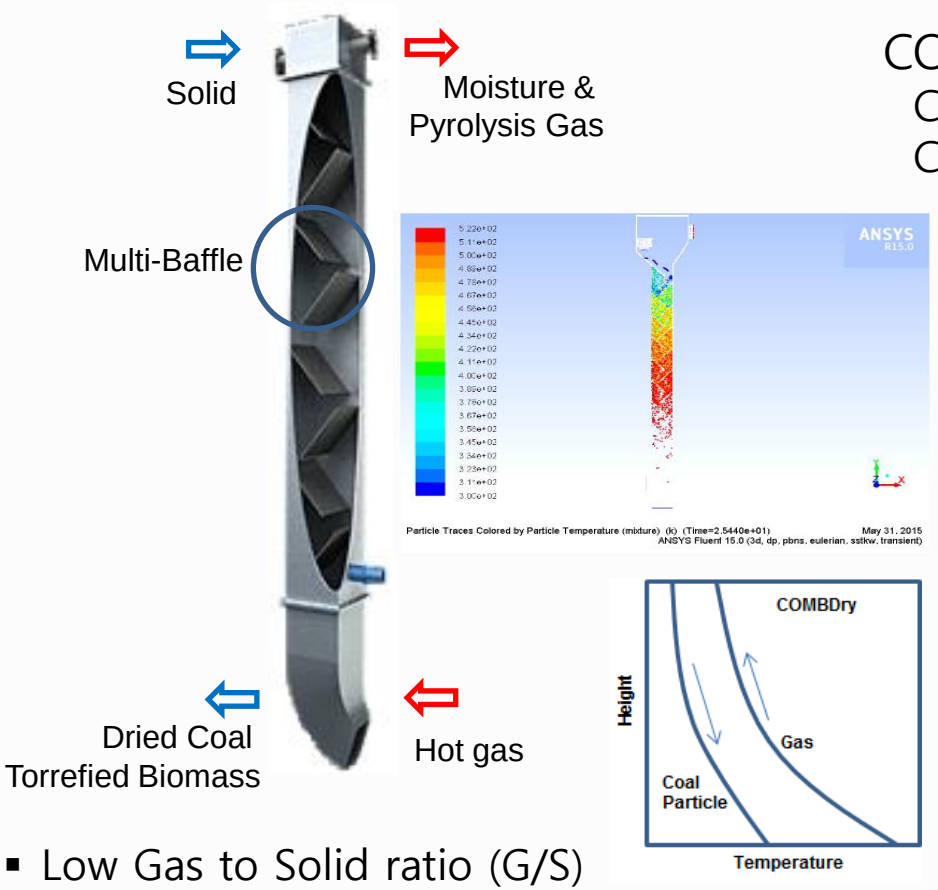
30 MW Coal Fired Power Plant (FBC)

Expected Results

- Moisture: 37% → 18%
- Heat value: 4,222 kcal/kg → 5,428 kcal/kg
- Combustion Stability: < 800 ℃ → 822 ℃
- Coal Feed Rate: 19.9 t/h → 14.3 t/h
- Combustion Air: 7.4% ↓
- Flue Gas: 11.6% ↓
- Bottom Slag & Fly Ash: 30% ↓
- FD/ID Fan Power: 7.7~11.5% ↓
- Boiler Efficiency: 2.9% ↑

Net effect: Positive

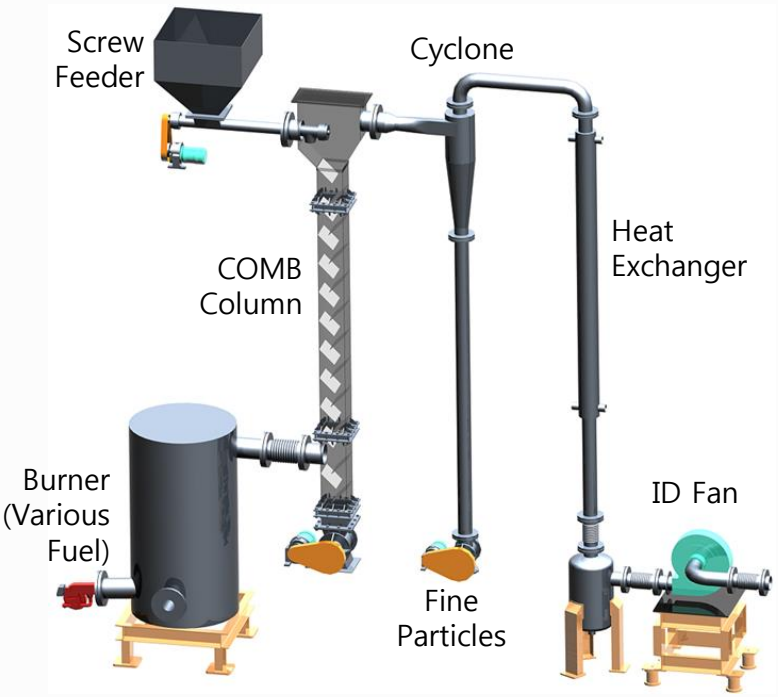
COMB Tech. for Coal Drying & Biomass Torrefaction



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
- Flexible & movable

Coal Drying : COMBDry™

Drying High Moisture Low Rank Coal

Purpose

- Indonesian low-rank coal upgrading with drying and stabilizing, securing coal for the national energy security

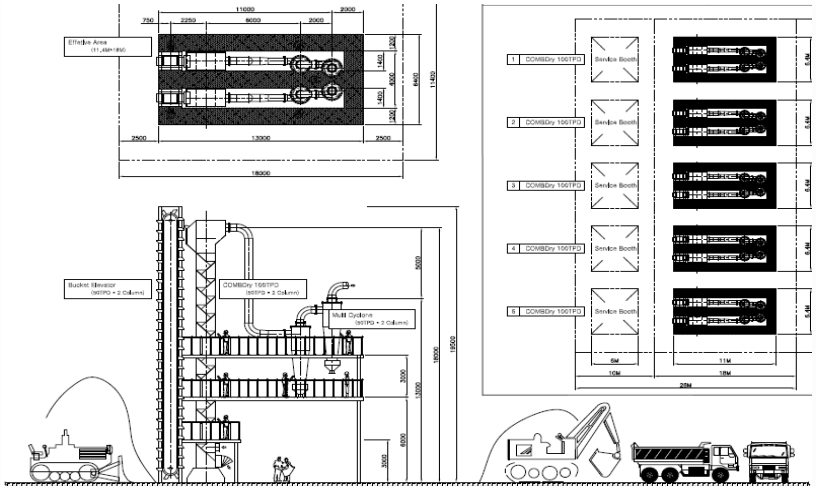
Progress and Plan

- Collaboration network built to jointly develop Indonesian low-rank coal
- MOU between KIER and tekMIRA in Indonesia established
- Demonstration site selection on a coal mine and a power plant underway in Indonesia

Achievement and Future Prospects

- **Discussion on technology application with tekMIRA and ARDEMR in Indonesia, BCIA, Energy Australia, Monash University**

20kg/hr, 50kg/hr BSU COMB (Counter flOw Multi-Baffle) facility



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

Biomass Upgrading : COMBPy™

Palm pellet & Black pellet from EFB & OPT

Purpose

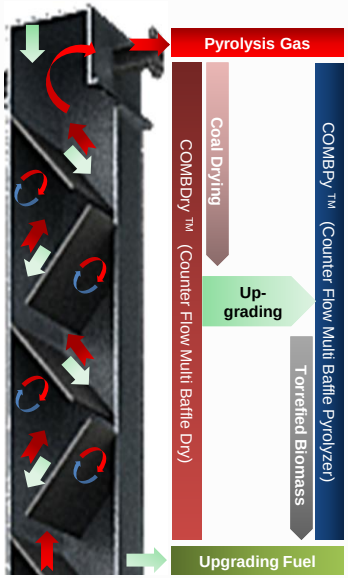
- Indonesia palm residues upgrading and utilization in combustion and gasification for CHP

Progress and Plan

- Demonstration and site selection on a POM underway in Lampung, Indonesia
- Demonstration 1MW combustion and gasification facility in Indonesia

Achievement and Future Prospects

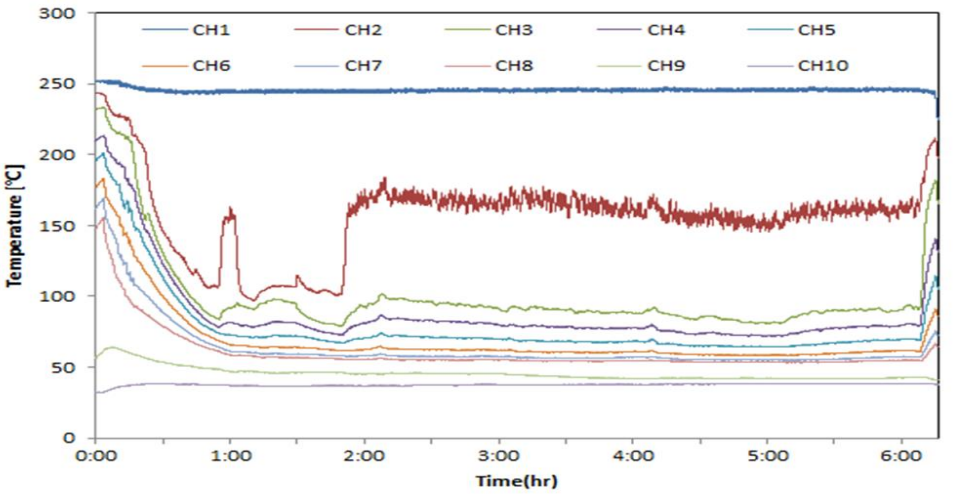
- Design package for industrial demonstration COMBPy/CHP plant made in 2018



Expanding concept of COMB for drying and torrefaction

Results : Coal Drying

Temperature profile along the column



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

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

	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

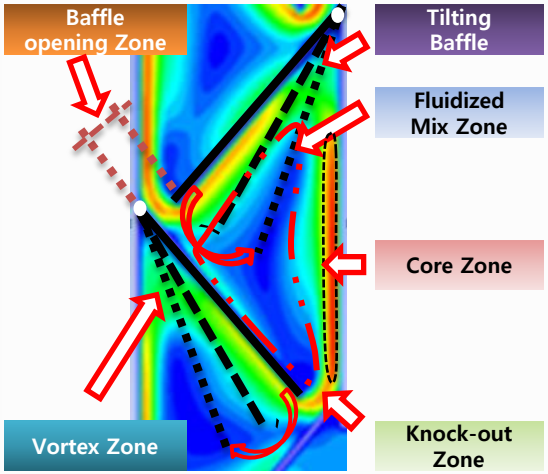
	Proximate Analysis (%, wt)				Calorific Value (kcal/kg)
	M	VM	FC	A	
Raw Biomass	19.04	64.31	16.06	0.59	3,892
COMBPy_250	2.65	77.55	19.25	0.65	4,569
COMBPy_280	1.69	77.18	20.35	0.78	4,699
COMBPy_300	0.92	76.03	22.33	0.93	5,015
COMBPy_320	0.7	70.62	27.62	1.07	5,088
COMBPy_340	0.6	69.02	29,25	1.13	5,112

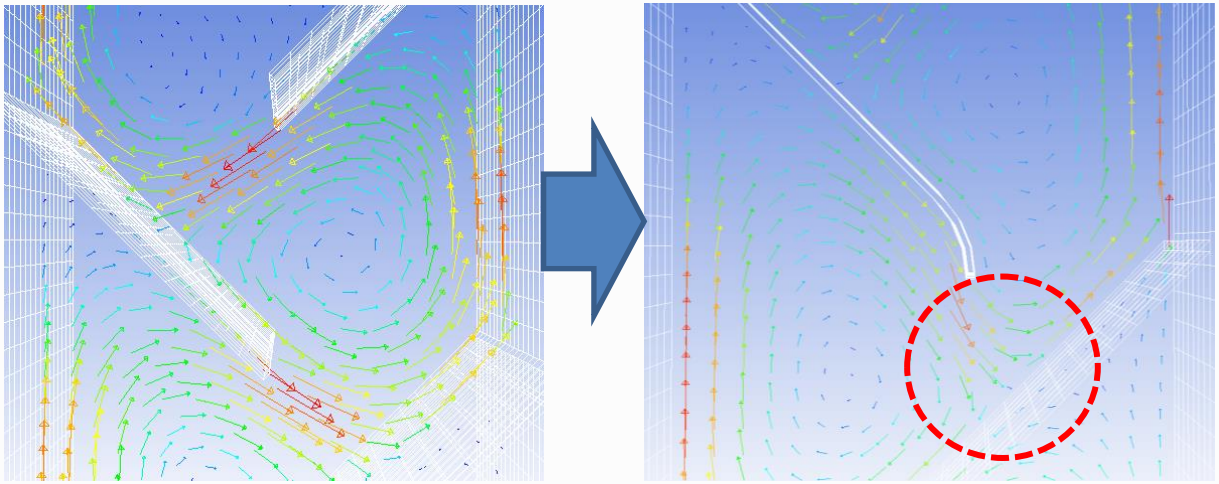
COMBPy_250 COMBPy_280 COMBPy_300 COMBPy_320 COMBPy_340

Target: 26MJ/kg (6,200kcal/kg)

Black pellet produced with residence time 3, 6, 8 min from left

Optimization





Standard Model　　Hybrid Model

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

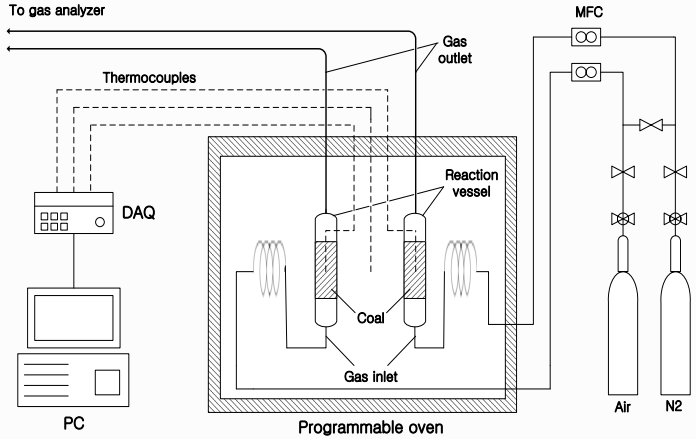
Scale (ton/day)	Width (m)	Core zone height (m)
1 TPD	0.15	0.72
5 TPD	0.257	1.23
100 TPD	0.7	3.34
500 TPD	1.19	5.72
1000 TPD	1.5	7.2

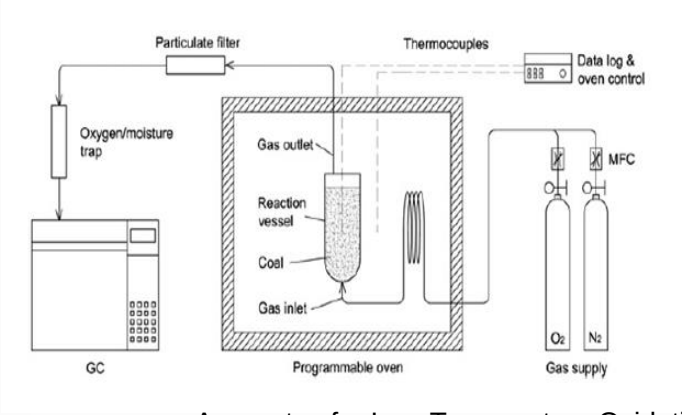
Scale-up factor

Activities of KIER's Clean Fuel Lab.

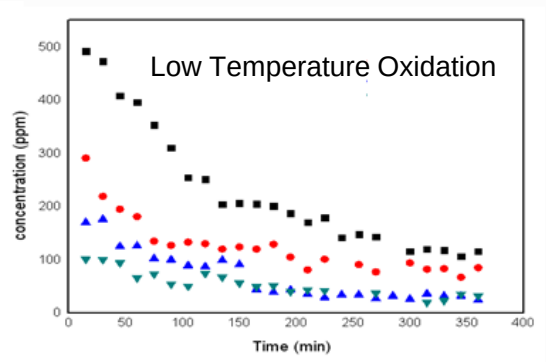
- Proximate/Ultimate/Calorific Value
- TGA/DTA (thermal properties)
- Ash analysis, ash behavior
- Functional Groups (FTIR) analysis
- CPT (Cross Point Temperature)/LTO (Low Temperature Oxidation) measurement for spontaneous combustion
- Water resistance/water re-adsorption after drying
- Briquetting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

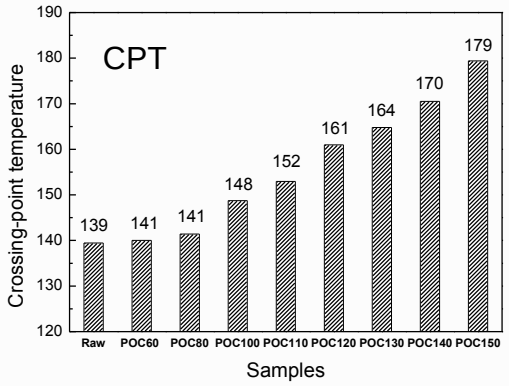
CPT Measurement Apparatus



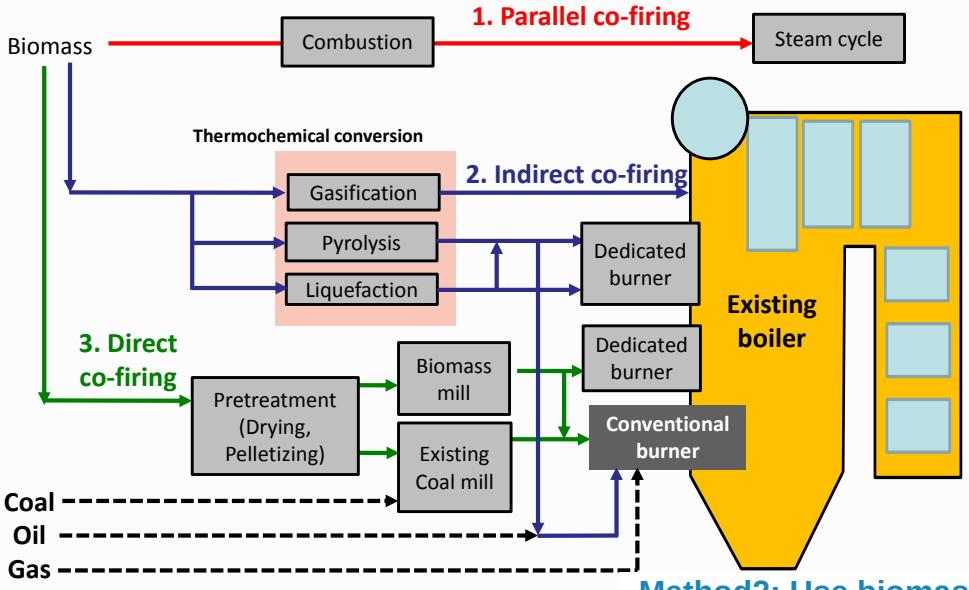


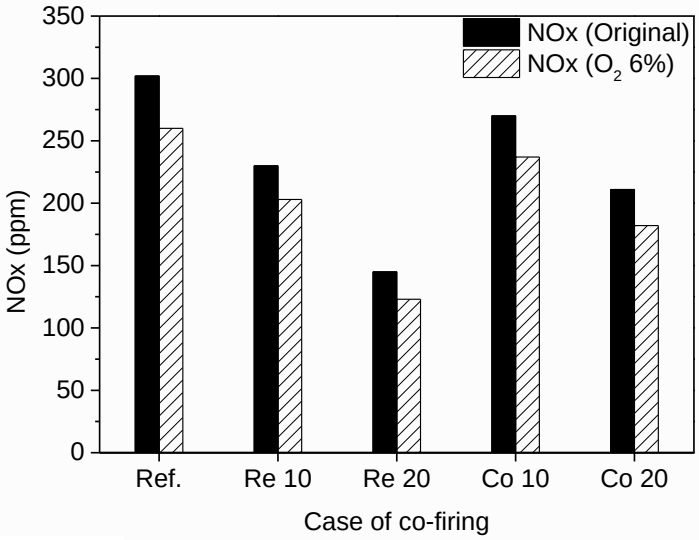
Apparatus for Low Temperature Oxidation



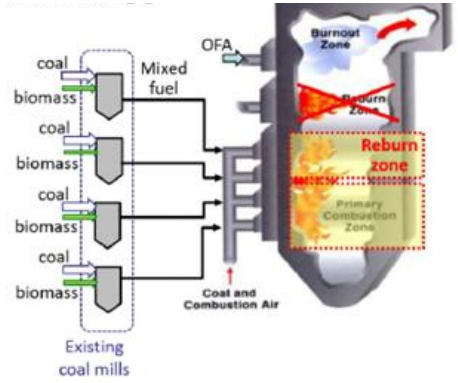


Biomass Co-firing

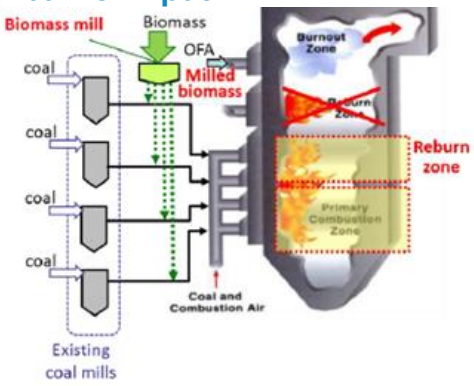




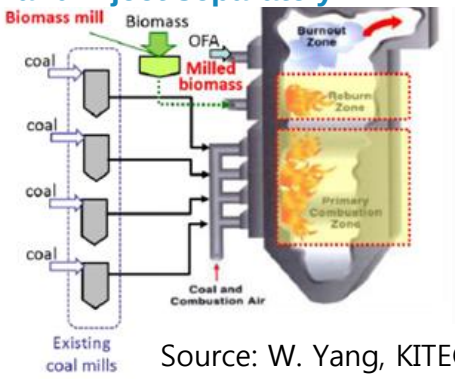
Method1: Blending coal and biomass at mill



Method2: Use biomass mill separately and blending at burner input



Method3: use biomass mill and inject separately

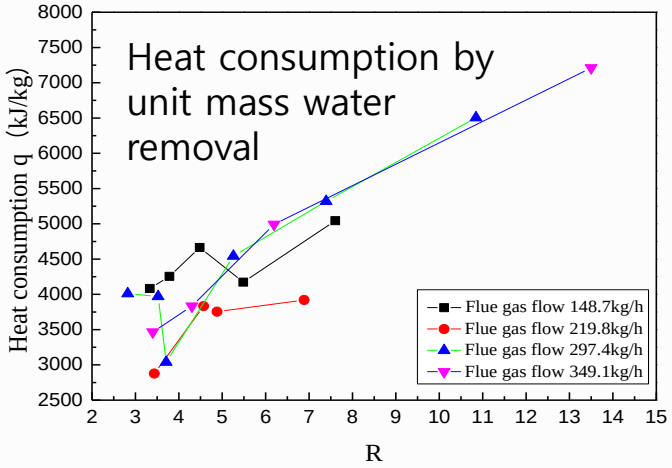


Source: W. Yang, KITECH (2016)

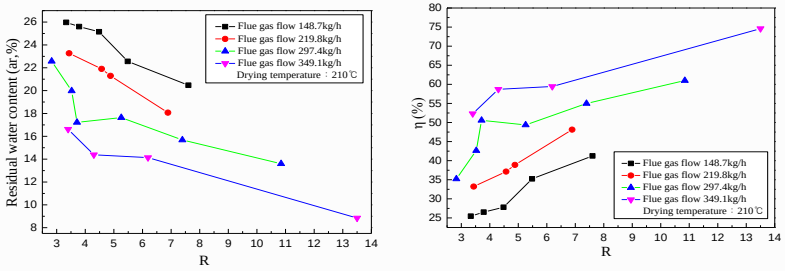
Cooperation China

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

HIT: Harbin Institute of Technology

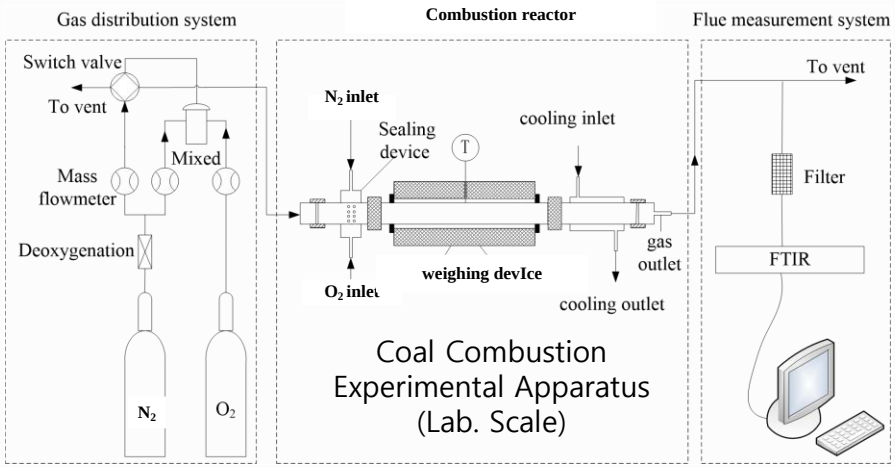


The drying efficiency and heat consumption reached the optimum value when the drying temperature was 210℃, and flue gas flow was about 300 kg/h, and R as 3.7.



Effect of *R* on lignite drying characteristics under different flue gas flow mass flux

Cooperation China



Coal Combustion Experimental Apparatus (Lab. Scale)

Combustion characteristic parameters under different drying temperature.

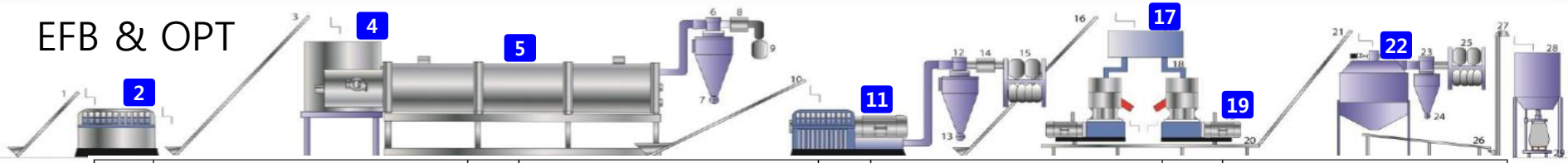
Parameters		Drying temperature						
	Raw	130℃	160℃	180℃	210℃	220℃	230℃	245℃
Ti (℃)	365	374	386	398	407	409	410	410
T∞ (℃)	563	572	586	595	610	609	612	615
Burnout time (s)	596	550	490	442	383	381	384	380
$(d_w/d_t)_{max}$	0.3460	0.3418	0.3397	0.3350	0.3310	0.3298	0.3296	0.3298
$(d_w/d_t)_{mean}$	0.2108	0.2266	0.2412	0.2578	0.2759	0.2820	0.2856	0.2904

Ti: Ignition temperature; T∞: Burnout temperature;
$(d_w/d_t)_{max}$: Maximum weight loss rate; $(d_w/d_t)_{mean}$:Average weight loss rate;

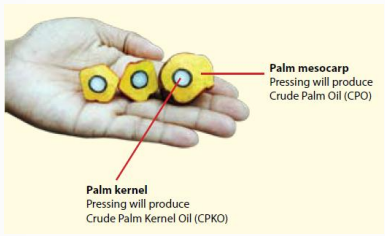
HIT conclusion:
The flue gas temperature of boiler was about 200℃ in actual power plant, the experimental condition in this research was in accordance with the **actual situation, so the results were applicable to technical upgrading in actual power plant.**

Cooperation Indonesia

EFB & OPT



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						



Fruitlets

FFB (Fresh t

EFB (Empty Fruit Bunch)

Palm Fiber

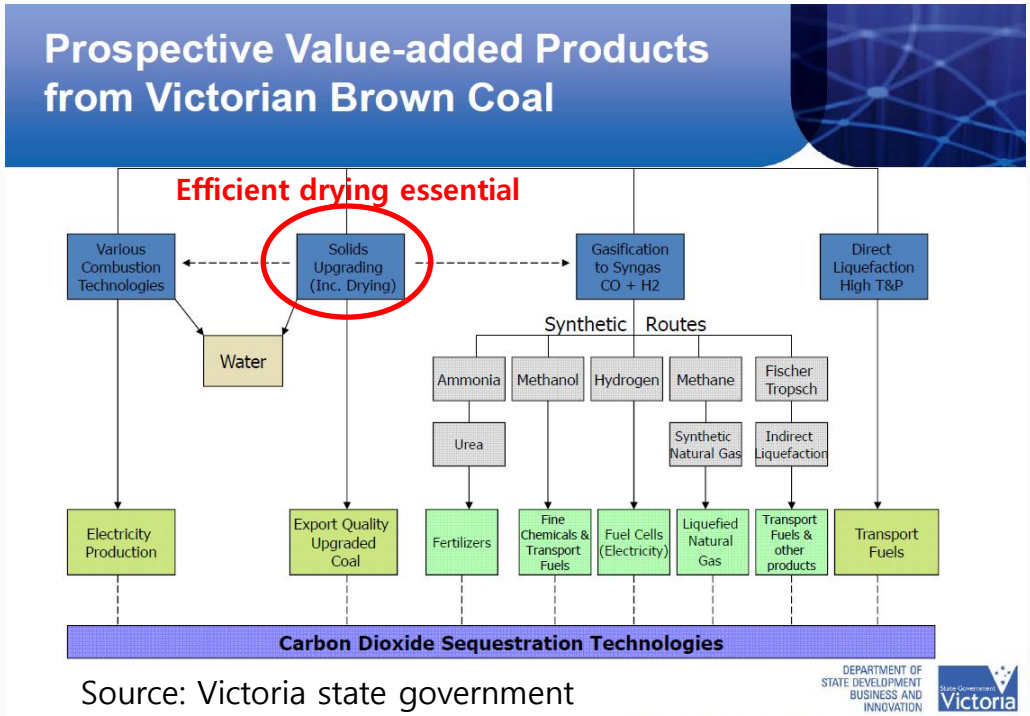
PKS (Palm Kernel Shell)

Substitute rotary dryer by COMB

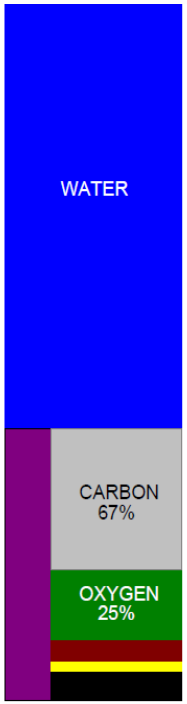
COMBDry : Drying to make palm pellet (20MJ/kg)
COMBPy : Torrefaction to make black pellet (26MJ/kg)

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

Cooperation Monash University, Victoria, Australia



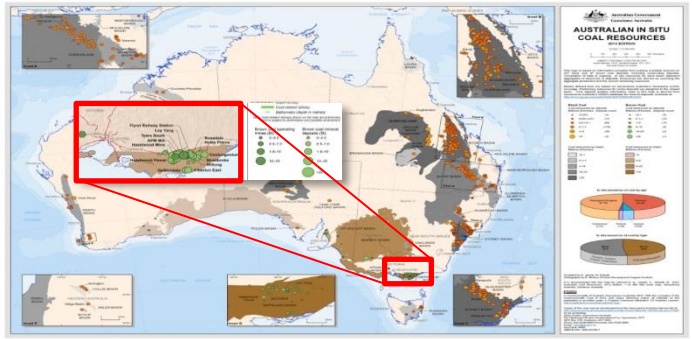
Source: Victoria state government



% weight
moisture
60-70%

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

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



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

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

Summary

Clean Coal Strategy in Korea
- USC, Retrofit, Fuel Switching, CCUS

USC
- 4 units of 1,000MW USC operation
- 10 units of USC under construction
- 1 units of USC FBC boiler under construction

Fuel switching
- Drying high moisture low rank coal
- Torrefaction of woody/herbaceous biomass
- COMB (Counter flOw Multi-Baffle) technology has been developed, 20kg/hr BSU, 50kg/BSU, 200kg/hr pilot operation
- Demonstration 2ton/hr are under discussion with international partners, China, Australia and Indonesia including ASEAN economies

KIER

GLOBAL KIER TECHNOLOGIES

Thank you!

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