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Oxyfuel Technology for CCUS Applied to Coal Fired Power Plants

IHI

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Contents

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1. What is Oxyfuel Technology for CCUS?

Concept of Oxyfuel Combustion

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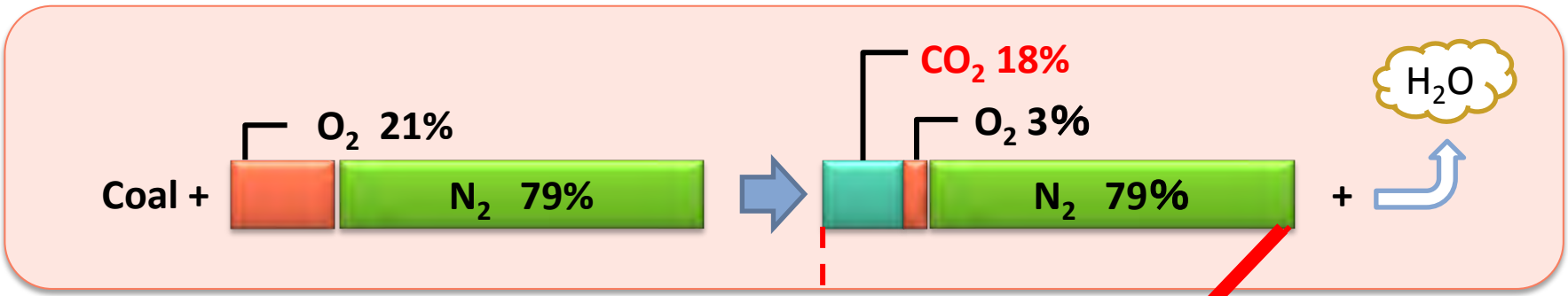
<Conventional air combustion>

As air contains N_2 and Ar by 79%, CO_2 concentration in flue gas is about 15% in combustion with air

Flue gas (dry base)



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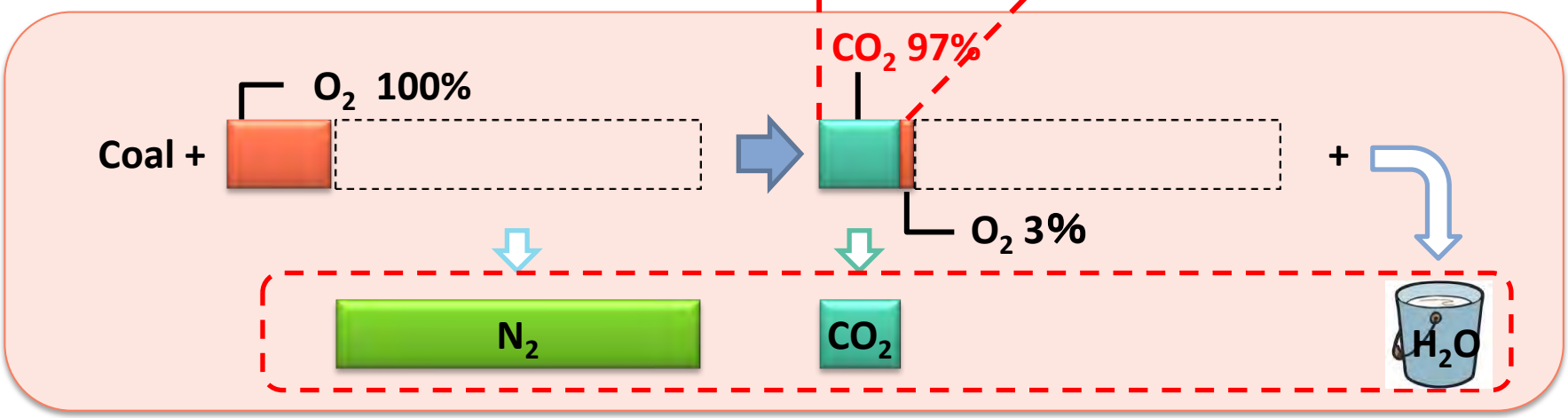
<Oxyfuel combustion>

In oxy-fuel combustion, since N_2 is removed before combustion, CO_2 concentration in flue gas is theoretically more than 90%.



Application to PC-Fired Boiler

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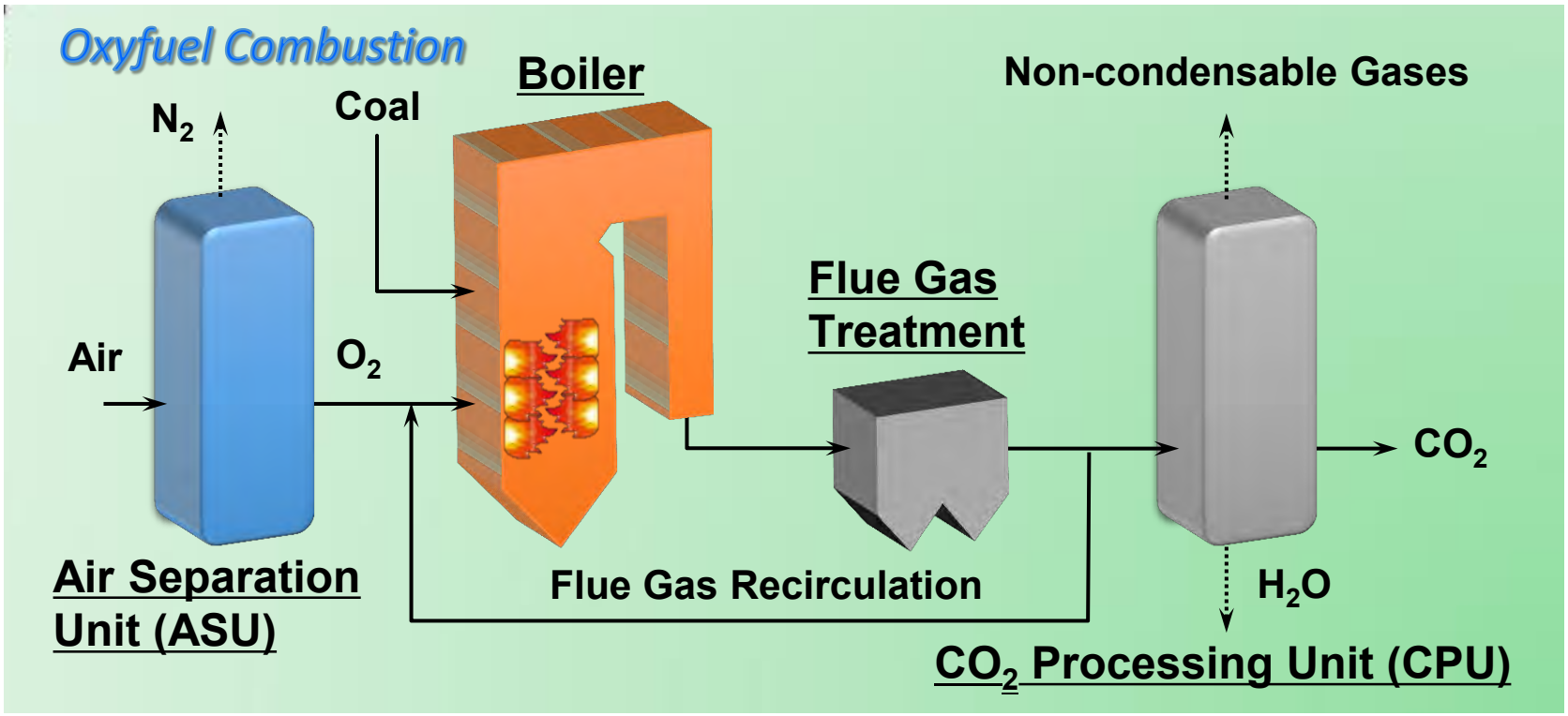
Oxyfuel Technology will convert coal power plants into clean power plants enabling longer operation by way of coping with the climate change issue, and will contribute to the environment and the economy of the community.



Features

- Applicable to both existing and new power plants
- Achievable of CO_2 capture rate up to 98% and nearly zero emissions
- Lower CO_2 capture cost for full capture
- Byproduct reuse such as N_2 resulting from air separation for O_2

Development Schedule of Oxyfuel Technology

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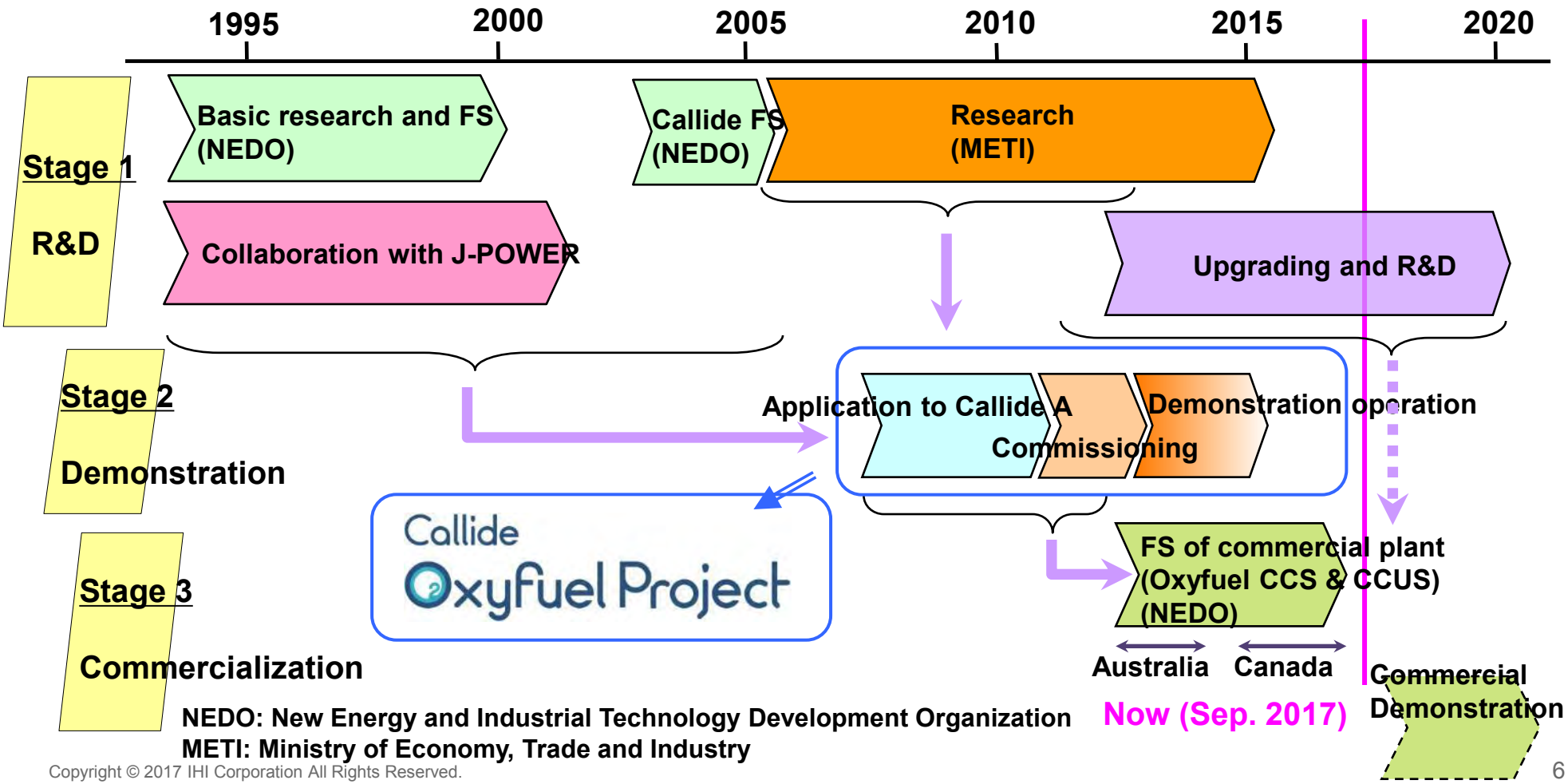
- IHI is one of pioneers in the development of oxyfuel technology, applying for patent in 1973 and starting R&D in 1989. Basic research and FS were carried out in the 1990's with Japanese partners.
- FS for demonstration was conducted in collaboration with Australian partners from 2004 and demonstration project commenced in 2008 ("Callide Oxyfuel Project").
- The demonstration ended in 2015 with the completion of CO_2 underground injection.



NEDO: New Energy and Industrial Technology Development Organization
METI: Ministry of Economy, Trade and Industry

2. Callide Oxyfuel Project

Callide Oxyfuel Project

Oxyfuel Project Partners

CS energy

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COAL21 FUND

GLENCORE

Schlumberger Carbon Services

J-POWER EPDC

MITSUI & CO., LTD.

Australian Government

Queensland Government

METI Ministry of Economy, Trade and Industry

Supporting Collaborator

JCOAL Japan Coal Energy Center

Callide Oxyfuel Project Overview

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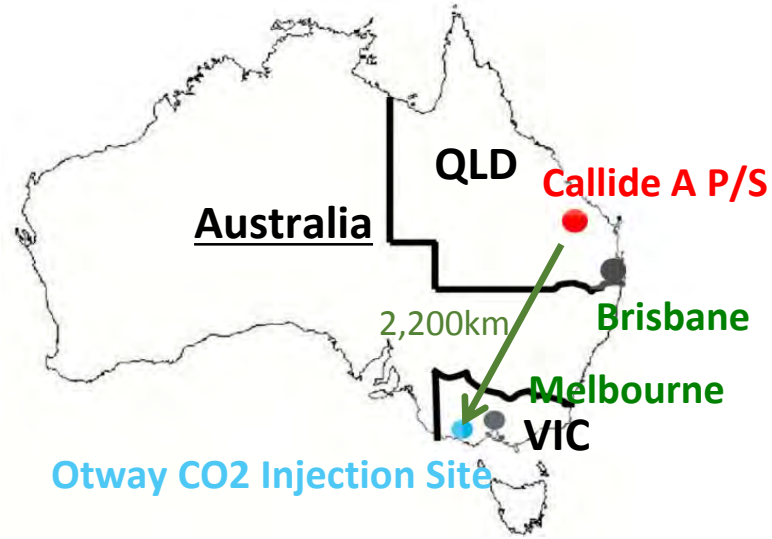

Features

The world's first and only oxyfuel power plant;

- ✓ having all processes required for commercial use
- ✓ selling electricity with capturing CO_2
- ✓ using existing old, not CCS-Ready, coal fired power plant

Injection of captured CO_2 into the underground;

- ✓ the world's first injection from oxyfuel power plant

Callide A Power Station
Owned by CS Energy
4 x 30 MWe
Steam: 136 t/h at 4.1MPa, 465°C
Commissioned: 1965 – 69
Refurbished: 1997/98
Placed in storage in 2002

Scope:
- **No.4 Boiler refurbishment**
- **2 x 330 TPD ASU**
- **Oxyfuel combustion Retrofit**
- **75 TPD liquid CO_2 recovery**
- **Trucking to CO_2 reservoir**
- **Injection and monitoring**

Callide Oxyfuel Project - History

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Boiler (Before modification)

Boiler (After modification)

Air Separation Unit (ASU)

CO_2 Processing Unit (CPU)

History of commissioning and operation

23 March, 2011	- First fire on fuel oil after retrofit
12 March, 2012	- First oxygen injection to boiler
19 March, 2012	- Successful 100% RFG and oxyfiring
14 Sept., 2012	- First oxyfuel flue gas to CPU
Oct. – Dec., 2014	- CO_2 captured was transported overland and injected underground
March, 2015	- Final oxyfuel operation

It achieved;

- over 10,000 hours of accumulated oxyfuel operation
- over 5,500 hours of CPU operation

Callide Oxyfuel Project – Modification

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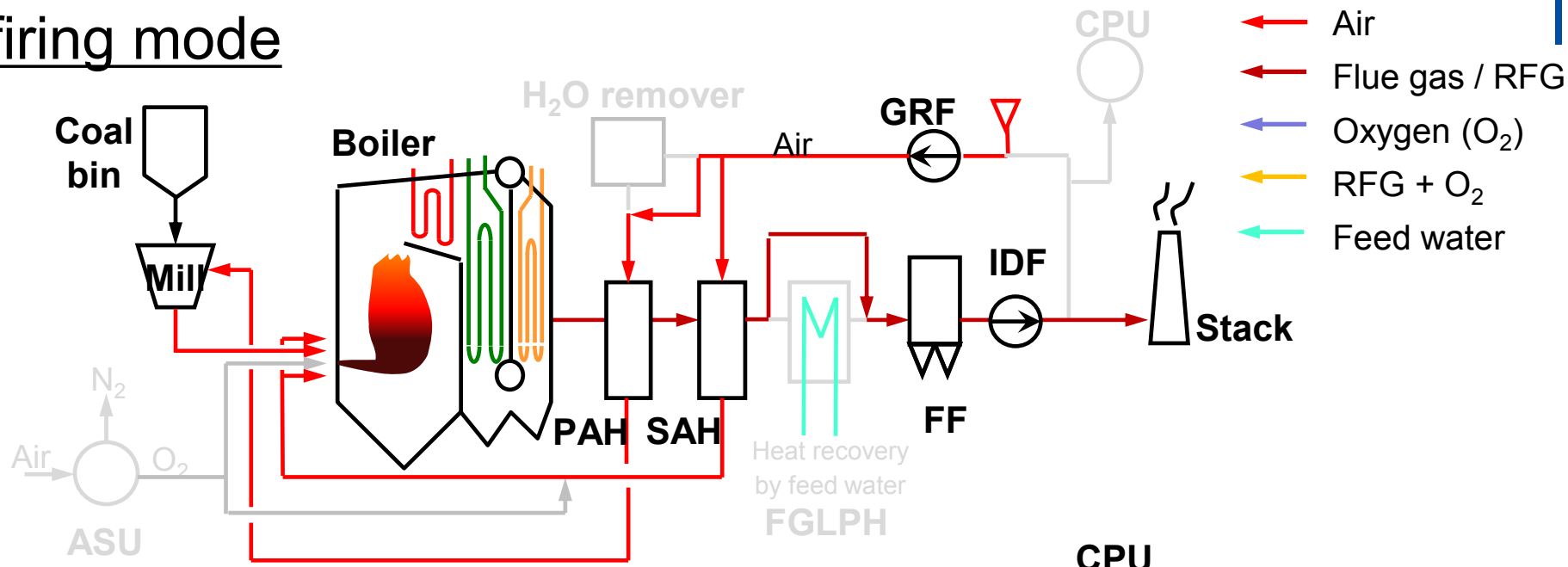
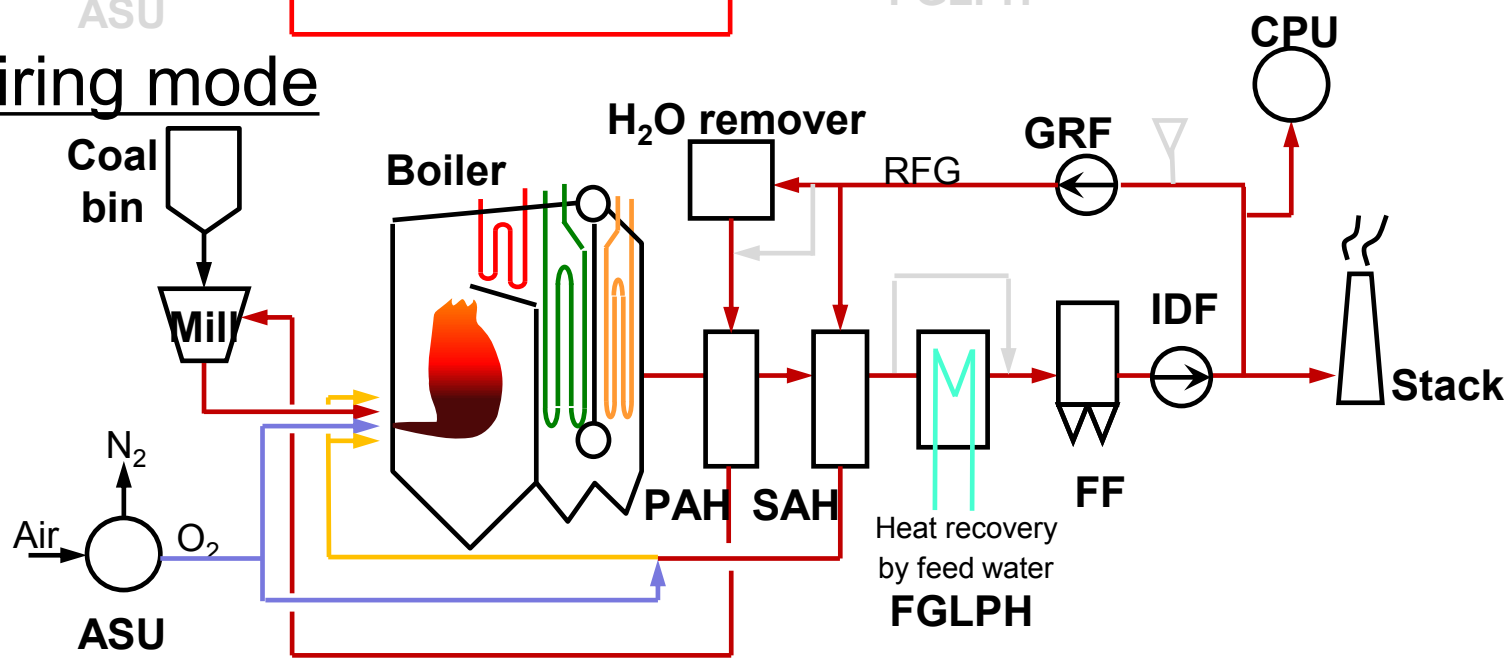
Air-firing mode



Oxyfiring mode



Conversion of Firing Mode - Results

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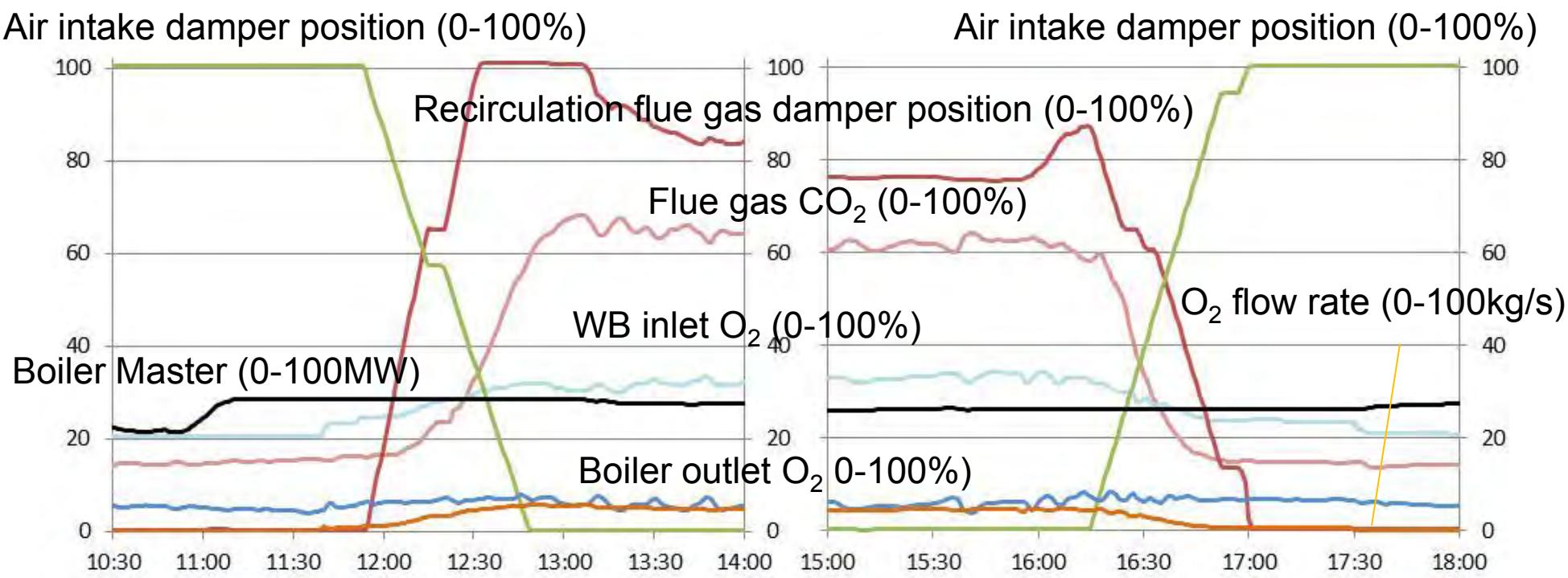
Mode conversion was smoothly operated between air-firng and oxyfirng



Performance of Boiler

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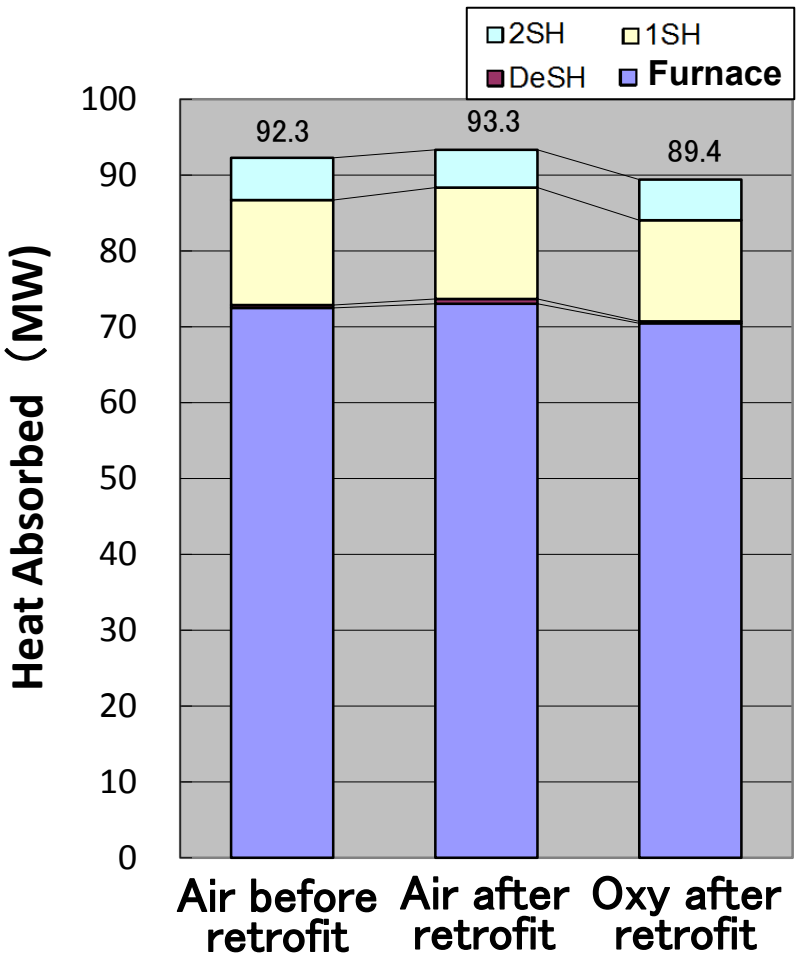
Heat balance of the boiler

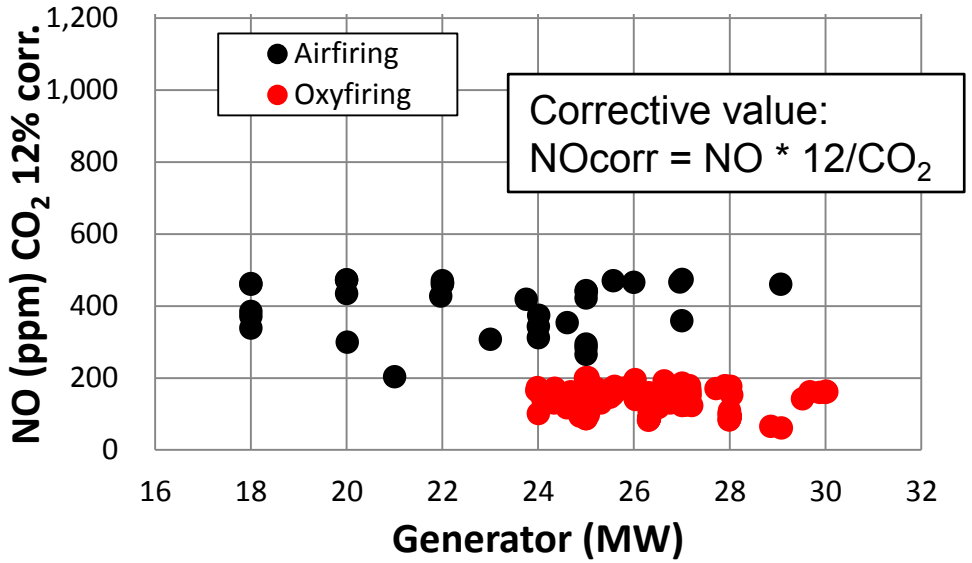
Heat absorbed in Oxy is 3 - 4 % smaller due to higher boiler efficiency and heat balance is almost same as in Air.

Air : 30MW, Oxy : 30MW (inlet-O_2 = 27%)



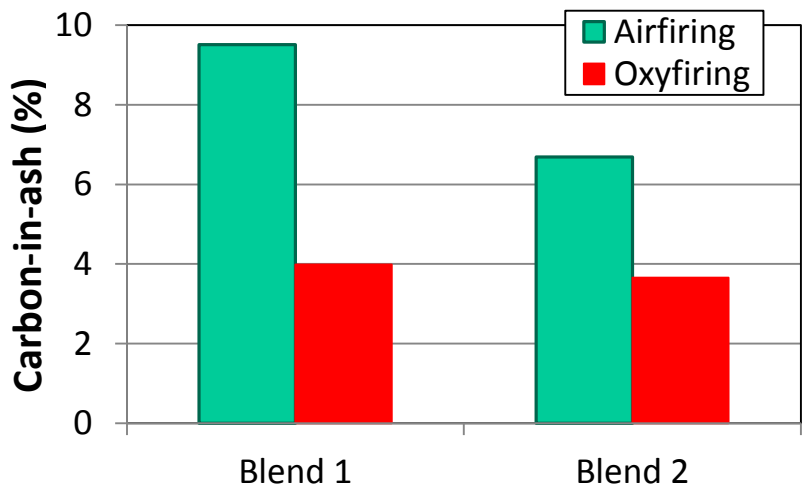
NOx emission

NOx from Oxy is about 1/3 of Air due to decomposition of recycled NOx in flame.



Unburnt carbon in ash

Reduced to a half mainly due to gasification



CO_2 Processing Unit (CPU)

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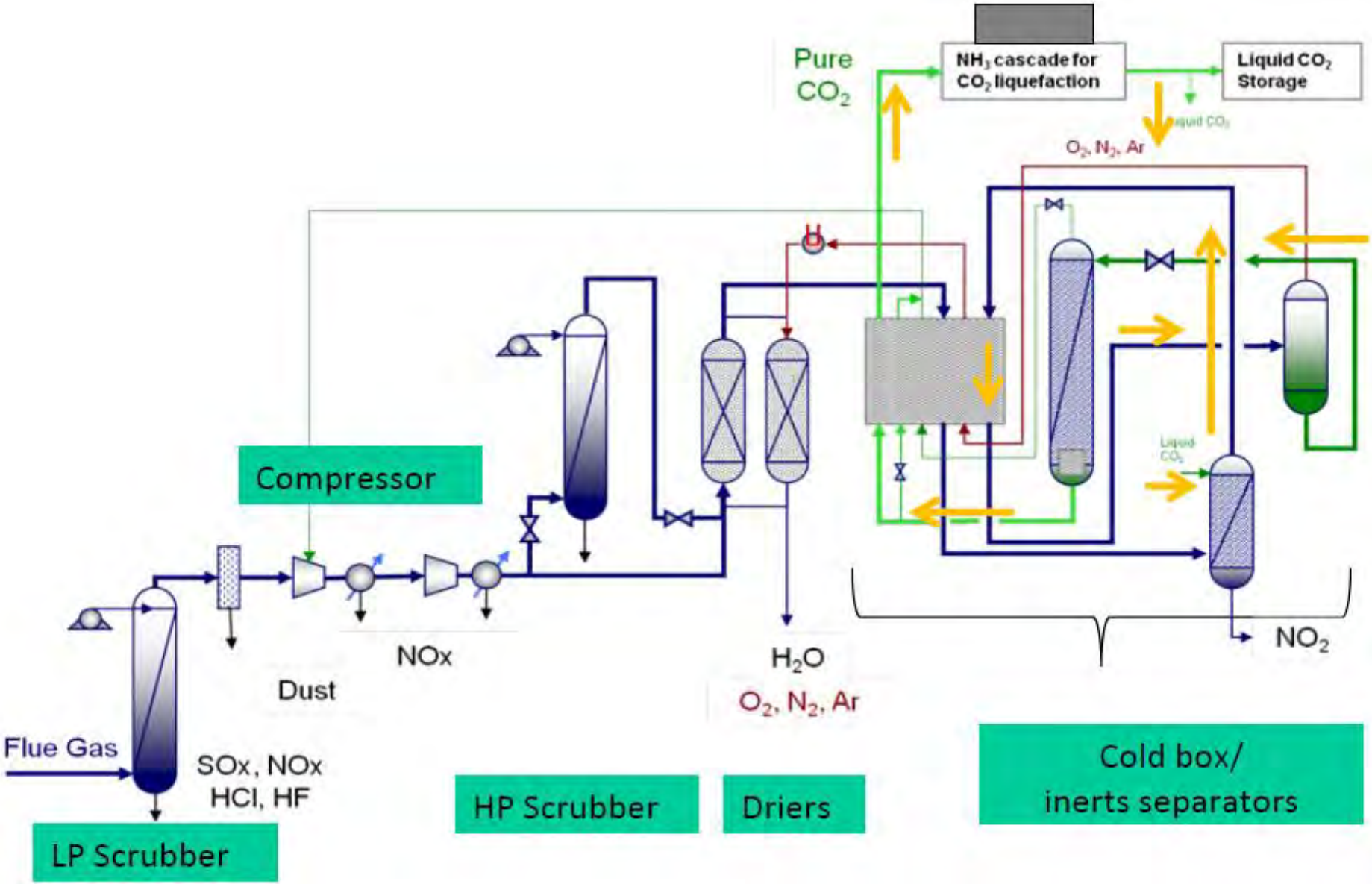

Courtesy of Air Liquide

CPU – Process gas quality (actual)

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Gas Composition	Unit of Measure	CPU - LP Inlet	CPU - LP Outlet	Product CO2
		From Boiler	To compressor	
Boiler Load Factor	%	80 - 100		
H2O	mol. %	19 - 22	5 - 7	< 20 ppm
O2	mol. %	3 - 5	3.5 - 6	< 30 ppm
CO2	mol. %	50 - 57	58 - 67	> 99.95
CO	ppmv	20 - > 200	25 - > 200	< 10
NO	ppmv	500 - 700	580 - 820	< 2.5
NO2	ppmv	20 - 40	Nil	< 20
SO2	ppmv	800 - 1000	< 10	< 0.1 ppm
SO3	ppmv	10 - 15	< 0.1	< 0.1 ppm
N2 (+ Ar)	mol. %	Balance	Balance	trace
Hg	ppbv	0.3 - 0.5	0.04 - 0.1	< 0.0002
	µg/Nm3	2.7 - 4.9	0.4 - 0.9	< 0.002
Particulates	mg/Nm3 (at 60 - 70% CO2)	150 - 250	< 0.02	nil
	mg/Nm3 (at 12% CO2)	20 - 50	< 0.01	nil

Behavior of Mercury

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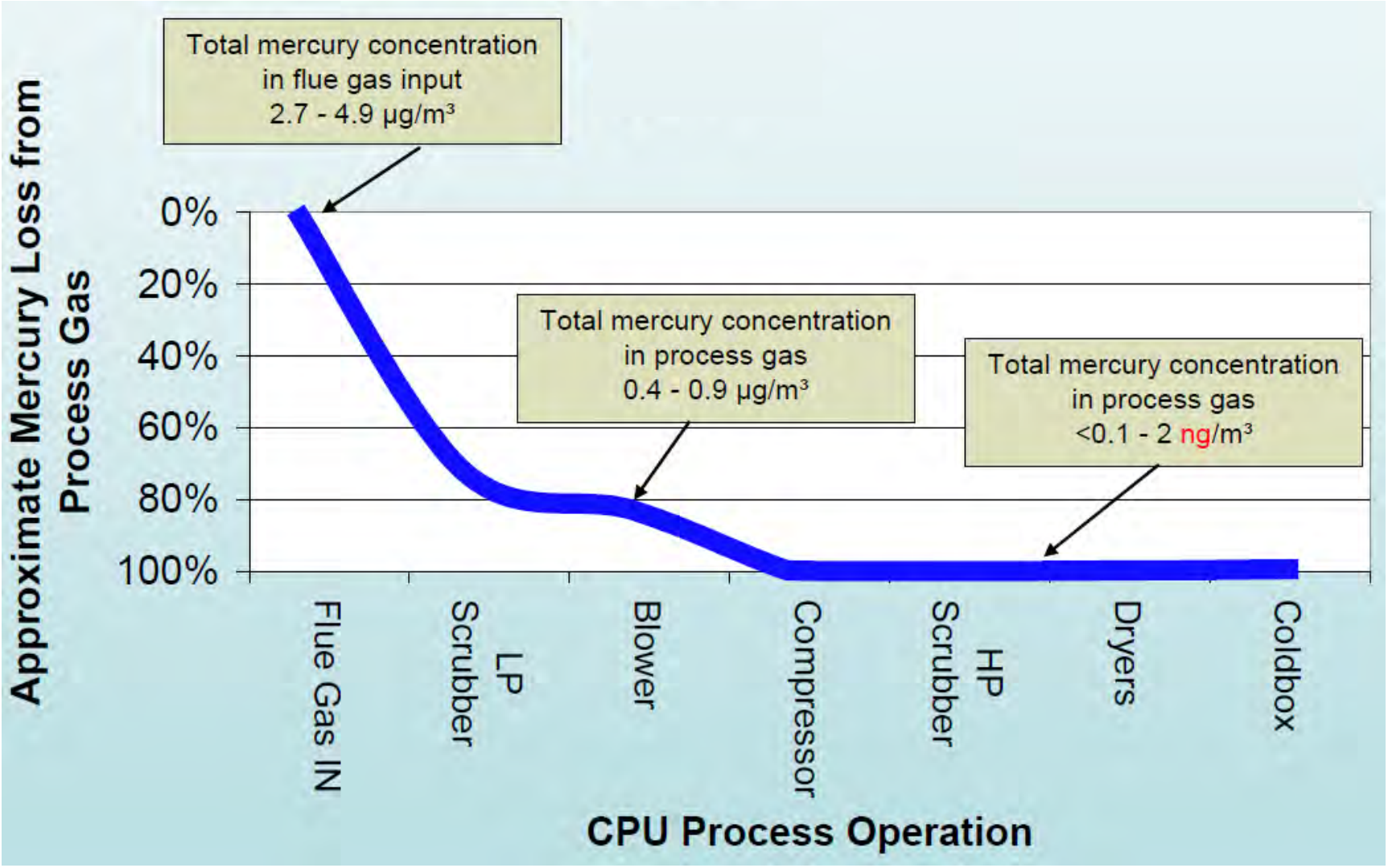

P. Nelson, et al., Measuring trace elements during the December 2012 Callide Oxy-Fuel trial, OCC3, 2013

CO_2 Injection Test

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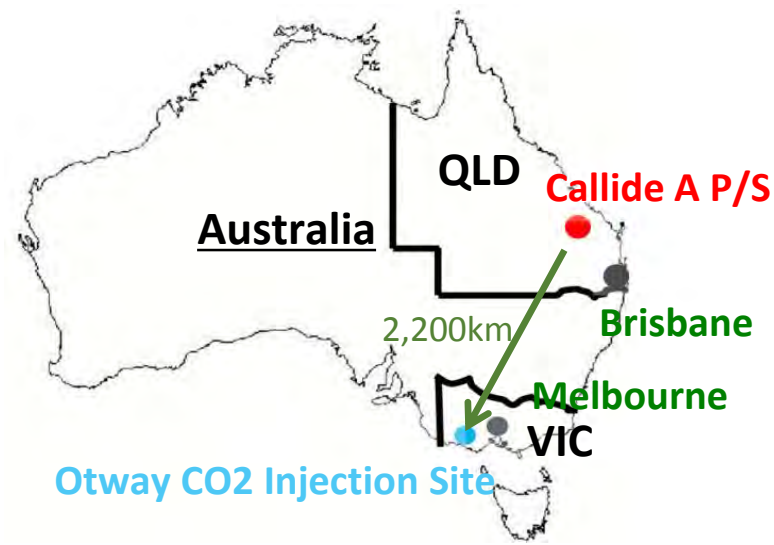
A part of CO_2 captured and liquefied at Callide power station was transported overland to the state of Victoria from October to December 2014 and was injected underground in the Otway Project Site of the CO2CRC (Cooperative Research Centre for Greenhouse Gas Technologies). The injected CO_2 was used to assess its geochemical and geophysical behavior in the storage layer. This was the first time in the world that CO_2 captured from an oxyfuel boiler in a coal-fired power plant was injected into underground. This was also the first time in Australia that CO_2 captured from a thermal power plant was injected into underground.

The objective of the project, a complete demonstration of total process from CO_2 capture to injection, was accomplished.



3. Business Model

World largest nitrogen plant for EOR（40,000t/day）

Linde:「Enhanced Oil Recovery」

Business Model of Oxyfuel Technology

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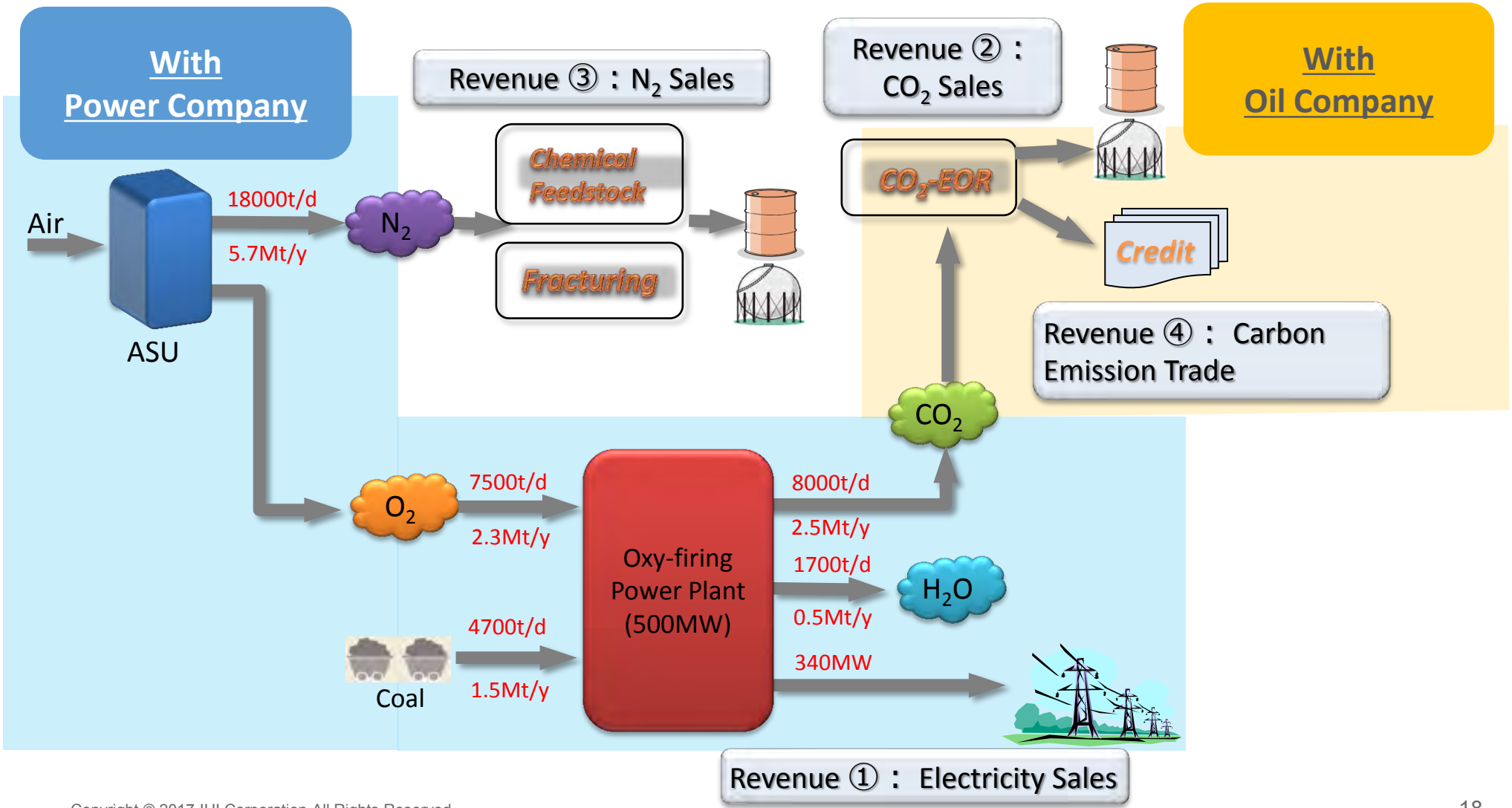
There are up to 4 revenue sources in the business model resulting from ①power generation, ②CO2 recovery, ③N2 separation, and ④CO2 emission reduction.



4. Conclusions

Conclusions

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- With the successful completion of its demonstration project, Oxyfuel is a proven technology ready for commercialization and will convert coal power plant(s) to clean power plant(s) with “zero emission”.

- With the optimization of up to 4 revenue sources and government support, Oxyfuel can be economically feasible and will contribute to improving the cost effectiveness of the power plant(s) whilst providing the pathway for future CO_2 emission reduction mandate and a countermeasure for carbon tax.

Acknowledgement

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Thank you for your attention.

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Realize your dreams