IEAGHG/IETS Iron & Steel Industry CCUS & Process Integration Workshop
Date: 5th to 7th November 2013
Tokyo Tech Front, Tokyo Institute of Technology, Japan

CCU Technology Development at RIST

November 5, 2013

Research Institute of Industrial Science & Technology

A Center of Expertise
RIST

Contents

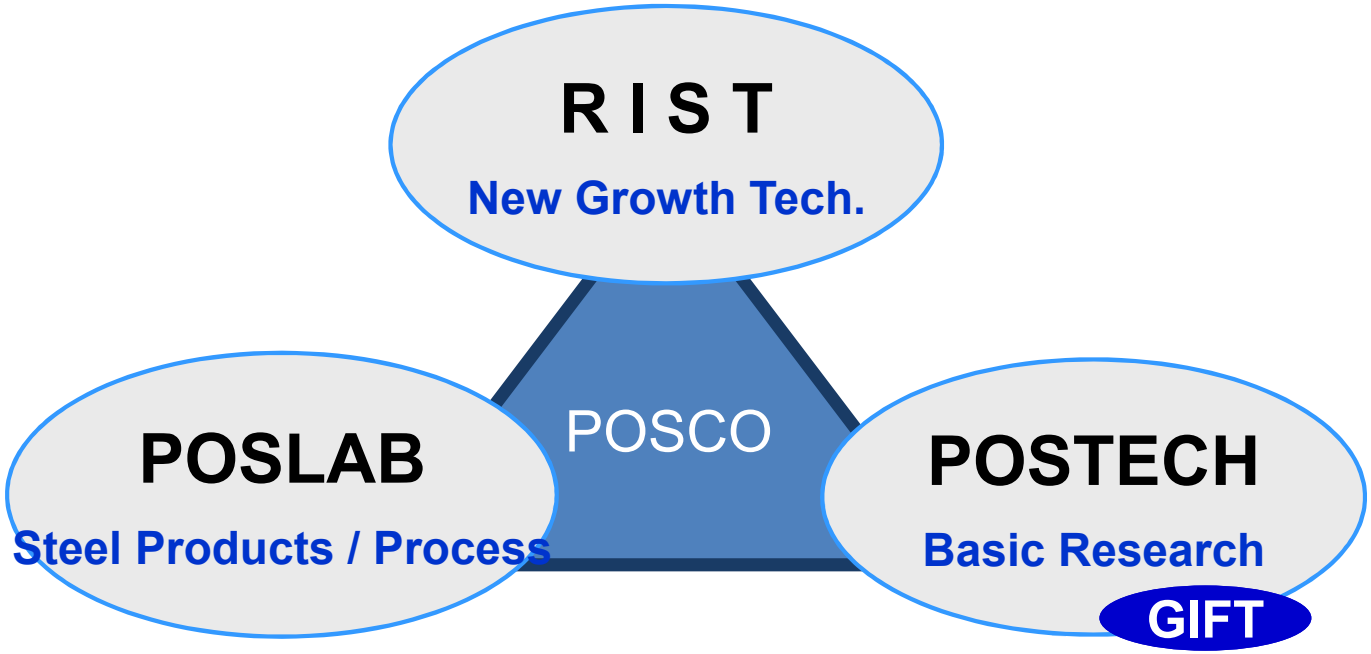
v RIST Overview

- R&D System of POSCO
- Organization
- R&D Achievements / Budget

v CCU R&D Activities

- Motivation
- CO_2 capture and utilization technology in iron and steel industry
- CO_2 Capture Using Aqueous Ammonia
- CO_2 Conversion using COG Reforming
- Heat Recovery from Molten Steelmaking Slag

❖ R&D System of POSCO



INSTITUTE	RIST	POSLAB	POSTECH
Established Date	March, 1987	July, 1994	November, 1986
Research Area	• Energy & Environment • Material & Processing • Steel structure & Architecture	• Product Development • Product Application • Process Development	• Education & Training • Basic & Advanced Research
Researchers	**257** (Ph. D 227)	**665**	**268**

*** Total 482**

* POSLAB : POSCO Technical Research Laboratories
* POSTECH : Pohang University of Science and Technology
* GIFT : Graduate Institute of Ferrous Technology

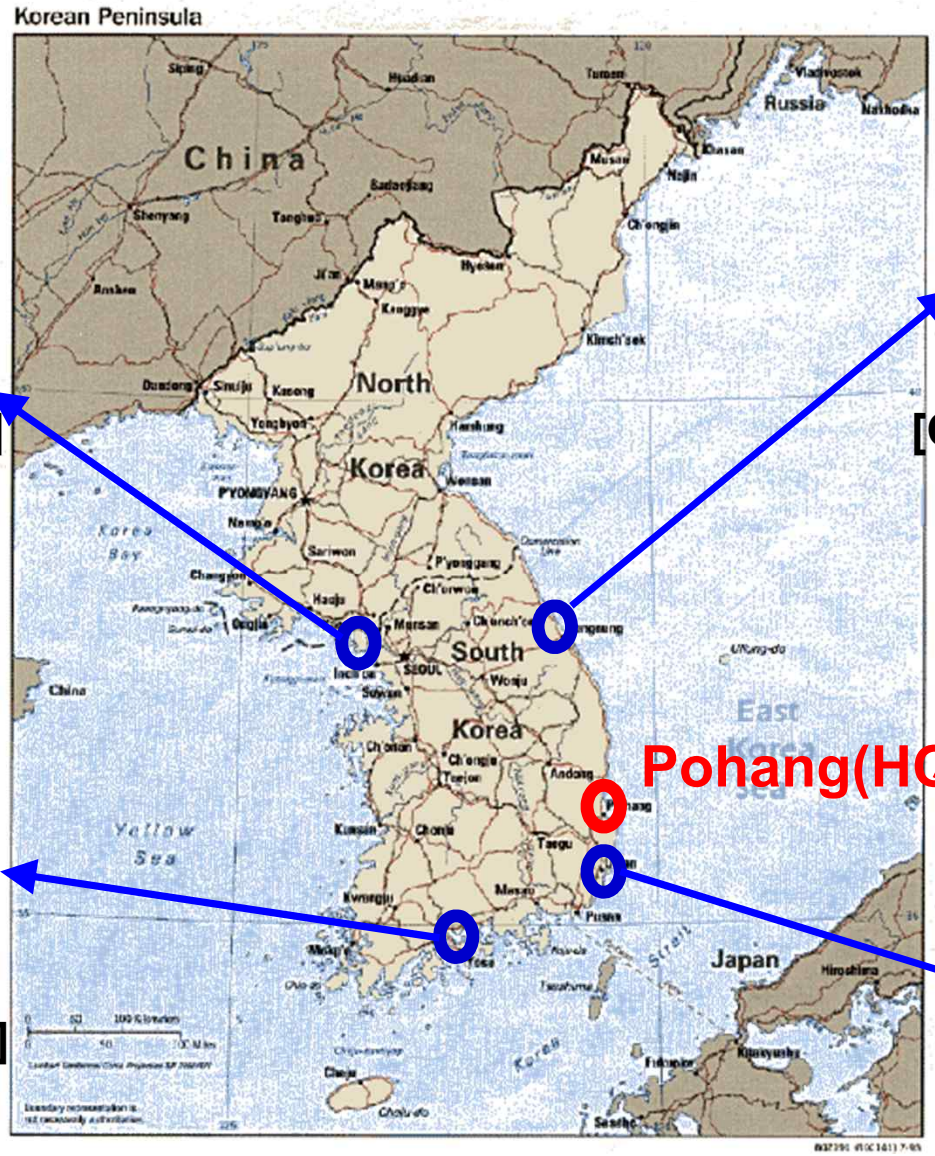
❖ RIST Location

[Songdo Global R&D Center]

[Gangwon Industrial Research]

[Gwangyang Envi. Research]

[Ulsan Plant Research]



Contents

v RIST Overview

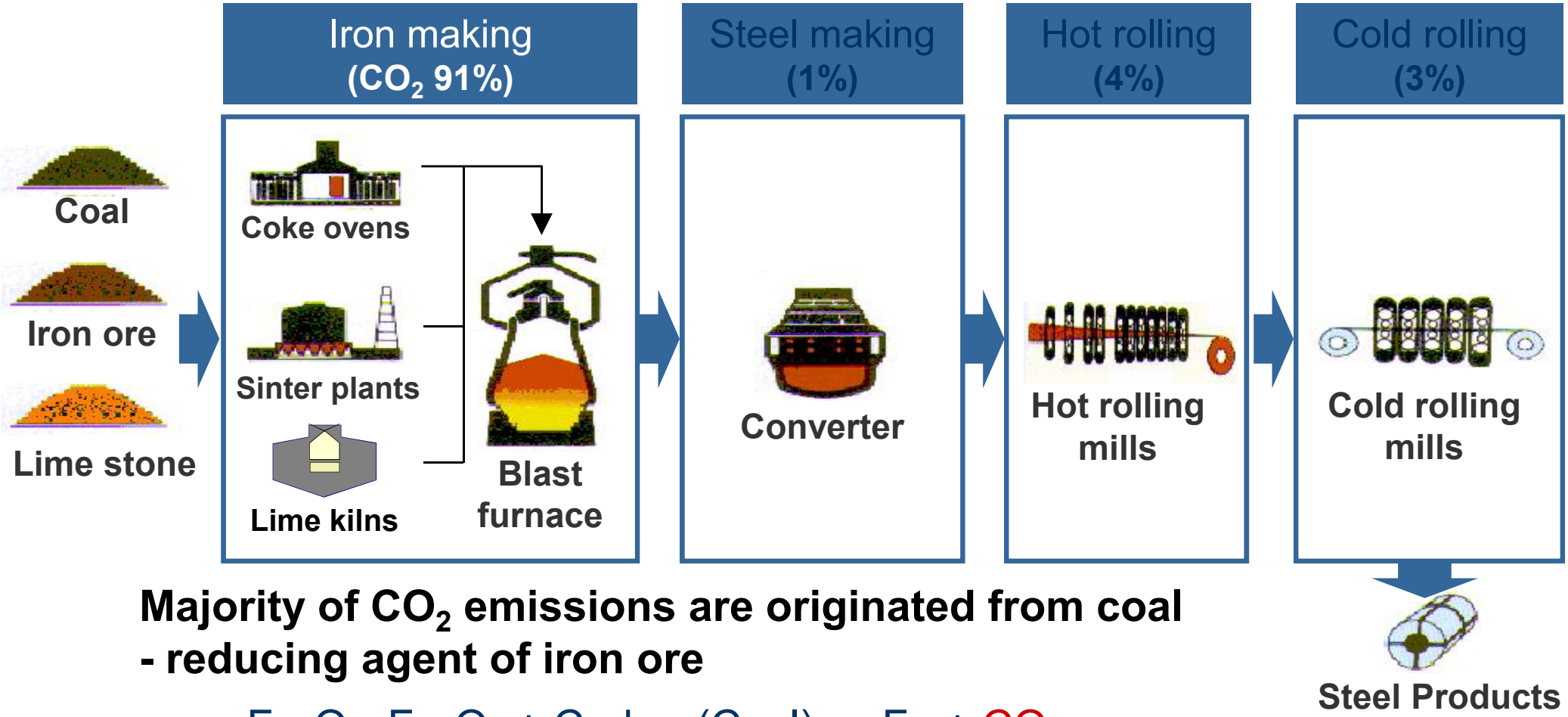
- R&D System of POSCO
- Organization

v CCU R&D Activities

- Motivation
- CO_2 capture and utilization technology in iron and steel industry
- CO_2 Capture Using Aqueous Ammonia
- CO_2 Conversion using COG Reforming
- Heat Recovery from Molten Steelmaking Slag

Iron & Steel Making Processes

- ☐ One of the largest CO_2-emitting sectors in industry
- ☐ 70 million ton-CO_2/year (~10% of CO_2 emission in Korea)



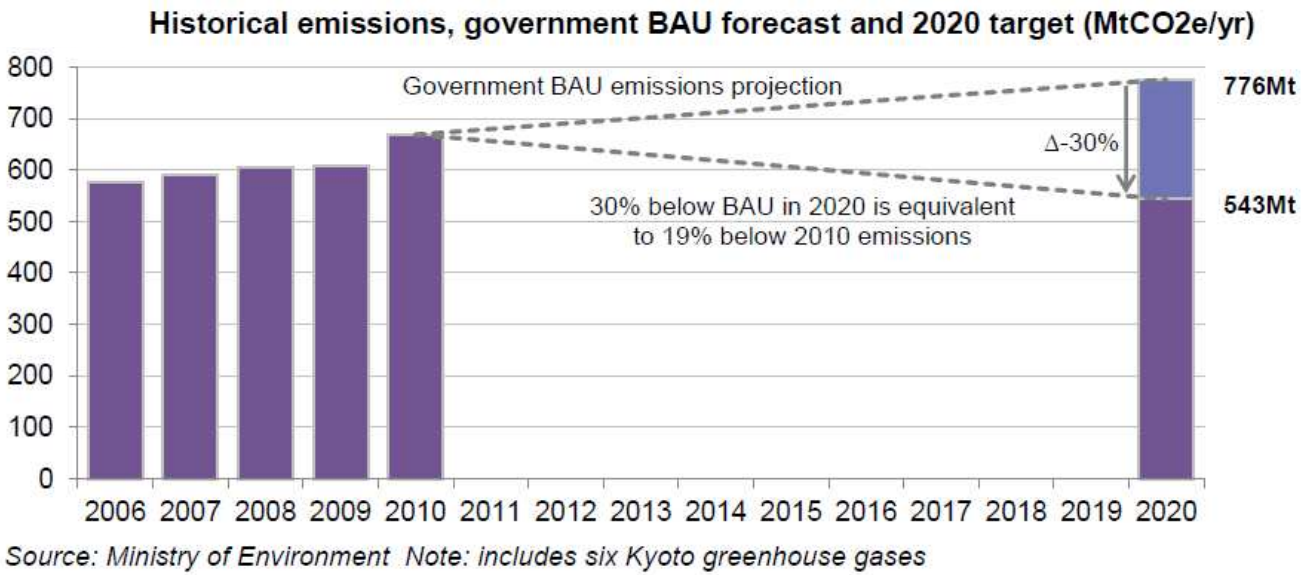
Majority of CO_2 emissions are originated from coal - reducing agent of iron ore

$$Fe_2O_3, Fe_3O_4 + \text{Carbon(Coal)} \rightarrow Fe + CO_2$$

Main reaction in Blast Furnace

ETS (Emissions Trading Scheme) in South Korea

- ☐ South Korea has approved a national emissions trading program to reduce the global warming pollution from its largest sectors by 2015.
- ☐ The ETS (emissions trading scheme) which comes into force from 2015, is designed to help the country reduce emissions by 30% by 2020, compared to business-as-usual levels.
- ☐ Steel industry is allocated 6.5% reduction target by 2020.



Source: Ministry of Environment Note: includes six Kyoto greenhouse gases

South Korea's 2020 GHG reduction target per sector (%)

Group/specific group	2012	2013	2015	2020
POWER				
Power generation, natural gas	1.5	3.0	6.1	26.7
INDUSTRIES				
Refined oil	0.4	0.6	2.8	7.5
Mining	0.4	0.4	0.6	3.9
Cement	0.3	0.5	3.0	8.5
Petrochemical	0.4	0.6	2.8	7.5
Paper, lumber	0.4	0.5	2.4	7.1
Textiles/leather	0.4	0.6	1.1	6.3
Glass/ceramics	0.4	0.5	0.7	4.0
Non-ferrous metal	0.4	0.5	0.7	4.1
Machinery	0.45	0.7	1.2	7.6
Electric/electronic	0.2	2.2	32.3	61.7
Electric other	2.4	3.4	26.3	39.5
Semiconductor	1.0	1.8	17.3	27.7
Automobile	0.3	1.1	15.2	31.9
Shipbuilding	0.5	0.6	1.3	6.7
Other manufacturing	0.2	0.2	0.3	1.7
Food and beverages	0.5	0.6	0.9	5.0
Construction	0.2	0.5	3.2	7.1
TRANSPORTATION				
Transportation	2.0	4.2	9.6	34.3
BUILDINGS				
Household	1.8	5.0	8.9	27.0
Commerce	1.9	4.4	8.8	26.7
PUBLIC OTHER				
Public other	5.2	8.6	15.7	25.0
AGRICULTURE/FISHERIES				
Agriculture/fisheries	0.0	0.1	1.7	5.2
WASTE				
Waste	1.3	2.0	9.0	12.3
TOTAL	**1.6**	**3.3**	**10.0**	**30.0**

Source: Presidential Committee on Green Growth

Motivation

Need for iron industry-specific CO_2 reduction strategy

☐ CO_2 Conversion to useful chemicals

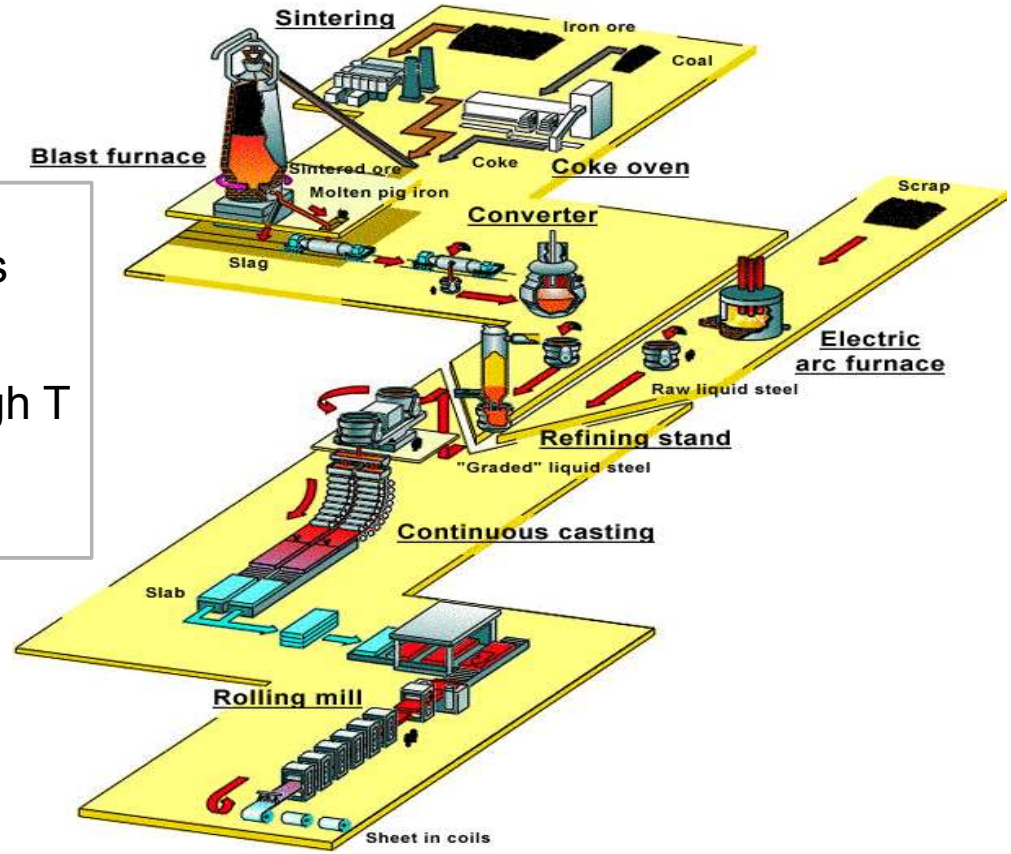
CO_2 + Reducing agent ⟶ Useful chemicals

▲Energy

Intensive CO_2

By-product/carbon (H_2, CH_4, Carbon)

Thermal E at high T (>500~1,000°C)



☐ CO_2 Capture & Utilization in Iron Industry

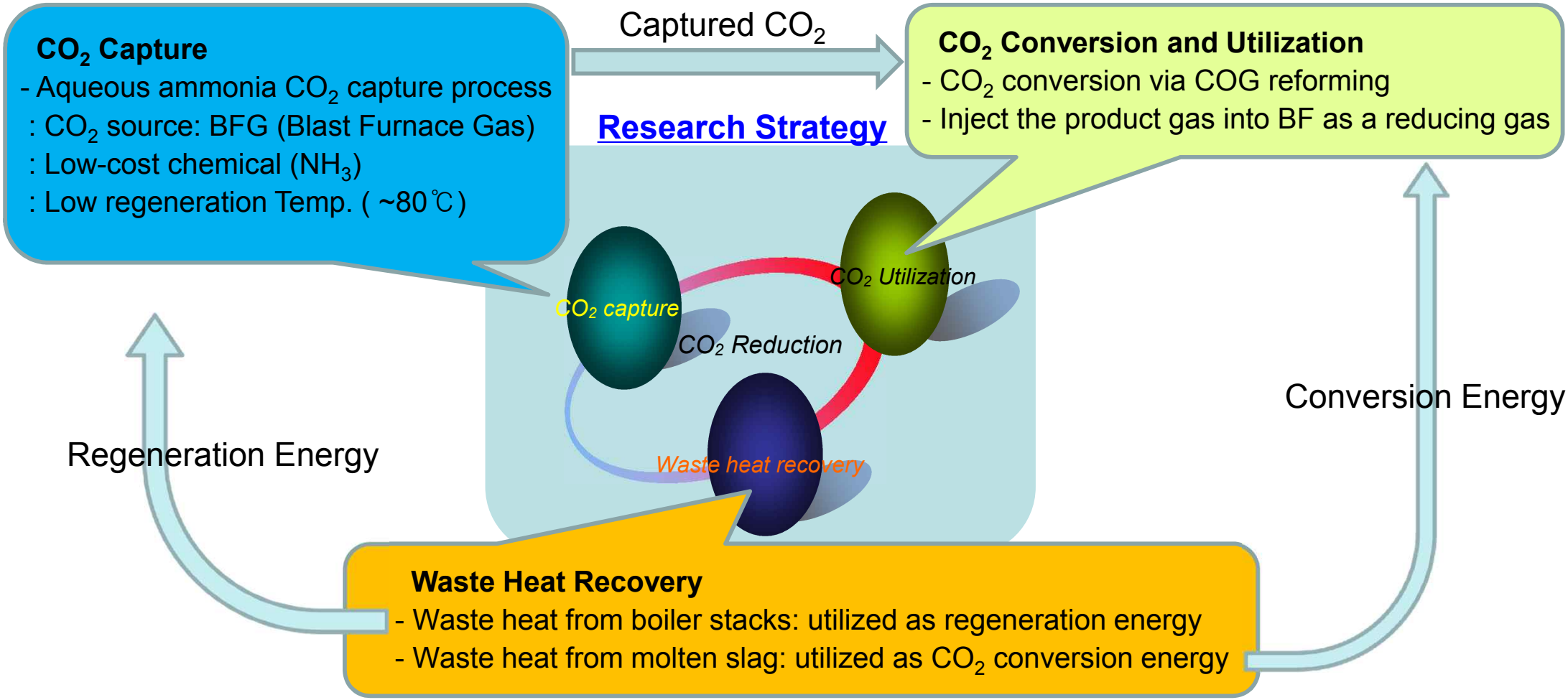
- Massive CO_2 emissions
- Substantial by-product gases (COG, LDG)
- Abundant waste heats

→ CO_2 capture & utilization (conversion) can be realized within the industry boundary.

CO_2 capture and utilization technology in iron and steel industry

☐ A concept of CCU within the steel industry boundary

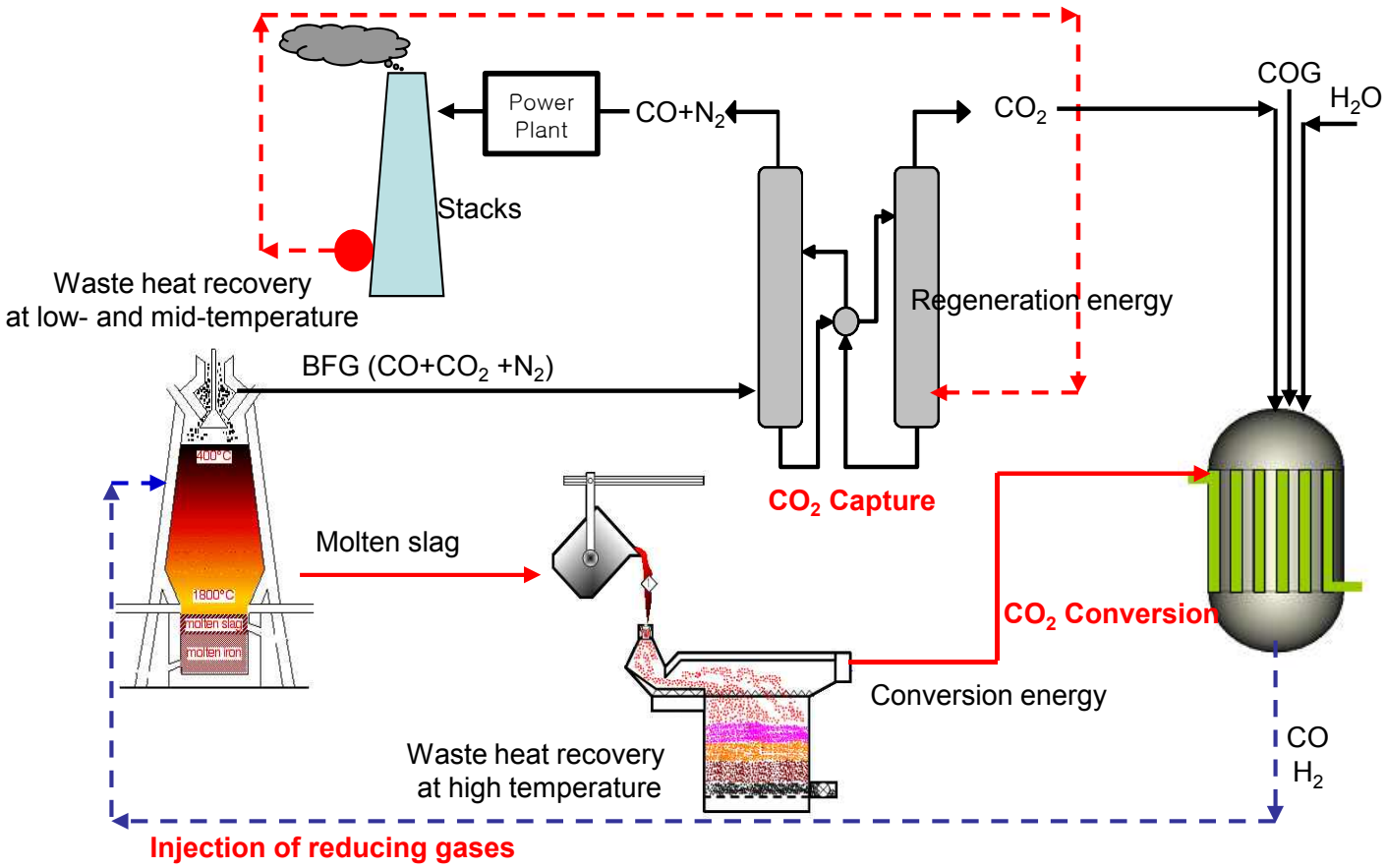
- CO_2 capture using aqueous ammonia, its conversion into reducing gases and injection of them into blast furnace



CO_2 capture and utilization technology for the iron and steel industry

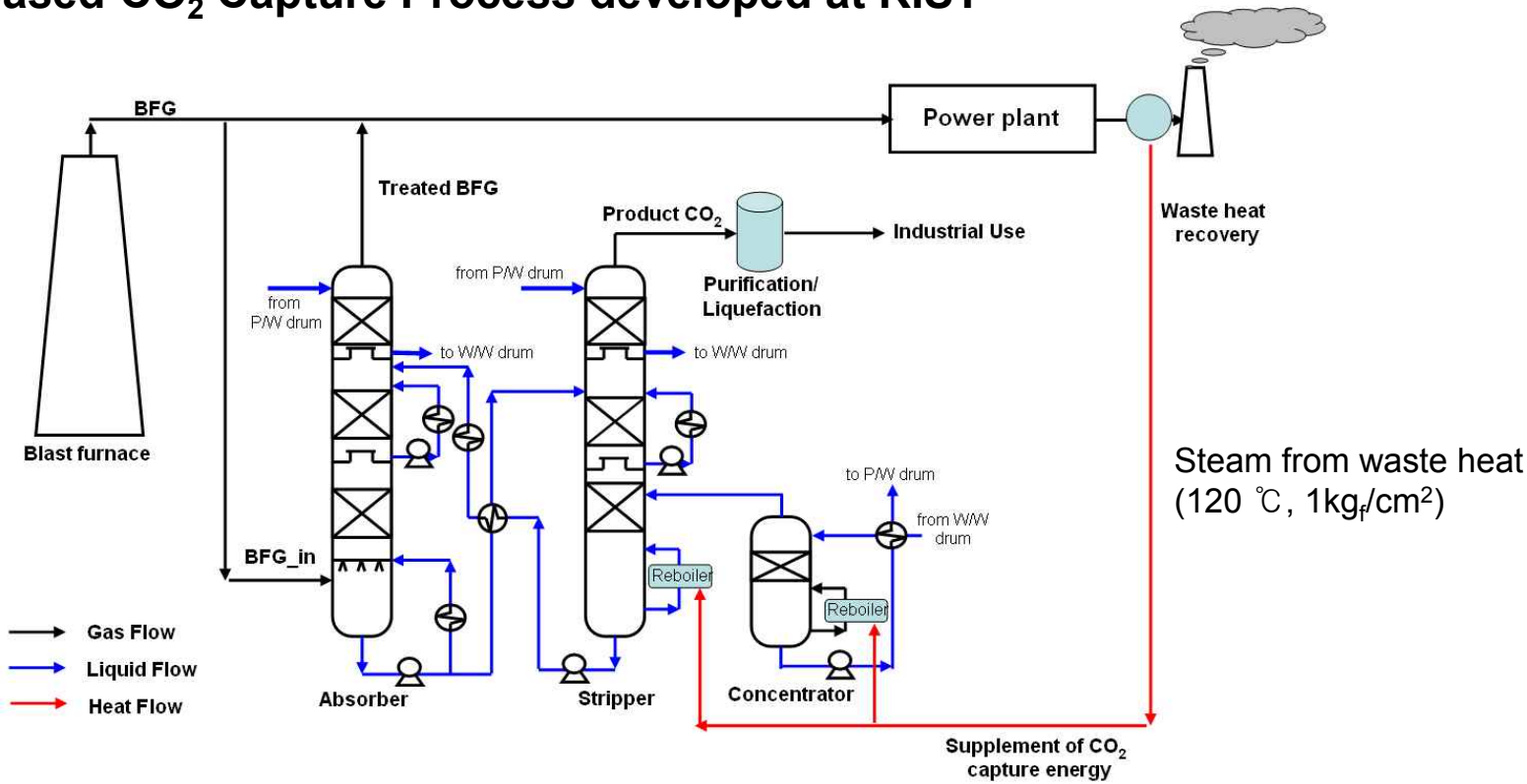
CO_2 capture and utilization technology in iron and steel industry

- ☐ **Project Name: Technology Development for CO_2 capture and utilization in iron and steel industry**
- ☐ **Project Due : '09.6 ~ '14.5 [Phase I : `09.6 ~ `12.5, Phase II : `12.6 ~ `14.5]**
- ☐ **Participating Organizations : RIST, POSCO, POSCO E&C, KIER, POSTECH, SKK Univ.**



CO_2 Capture Using Aqueous Ammonia (I): Concept/Feature

☐ Ammonia-Based CO_2 Capture Process developed at RIST



Steam from waste heat (120 ℃, $1kg_f/cm^2$)

☐ Technology Feature

- Feed gas: BFG
- Absorbent solution: low concentration aqueous ammonia solution (< 10 wt %)
- Waste heat recovered from stack gas and used as the regeneration energy

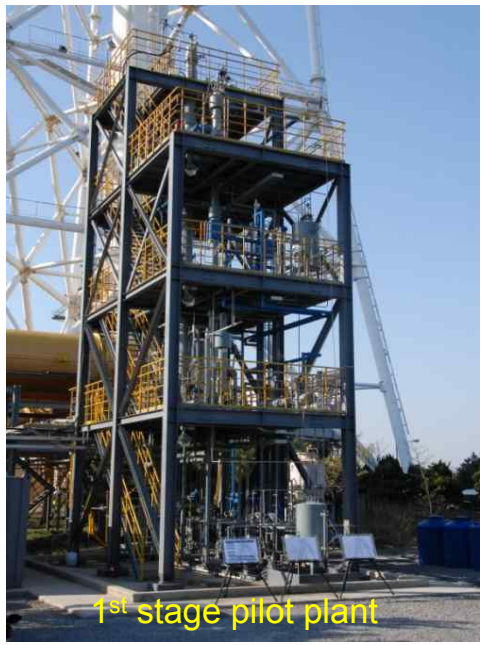
CO_2 Capture Using Aqueous Ammonia (II): Milestones

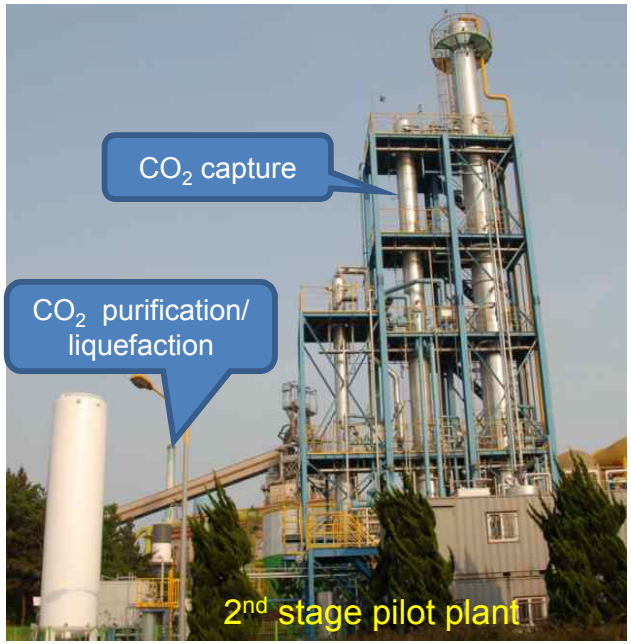
☐ R&D history

- Lab-scale research (2006~2007)
- 1st stage pilot plant research (2008-2010): 50 Nm^3-BFG/hr (Dec. 2008)
- 2nd stage pilot plant research (2010-2014): 1,000 Nm^3-BFG/hr
  - One-site pilot tests are on-going (May 2011-), Purification/Liquefaction facilities integrated (Apr. 2012-)

☐ 2nd Pilot Plant Spec.

Item	Spec.
Feed Gas	BFG (Blast Furnace Gas, CO_2 ~ 22%)
Feed Gas Flow rate	1,000Nm^3/h
Absorbent Sol.	<10% NH_3
Product CO_2	10 t-CO_2/d, 0.5MW power plant
Purity of product CO_2	>95% (Gas)
	>99.8% (Liquid)





☐ Test Results

- CO_2 recovery > 90%, L-CO_2 purity > 99.5%

☐ Further Plan

- Long-term continuous operation
- Additional pump around and higher NH_3 concentration in absorbent solution
- Basic engineering design for commercial scale

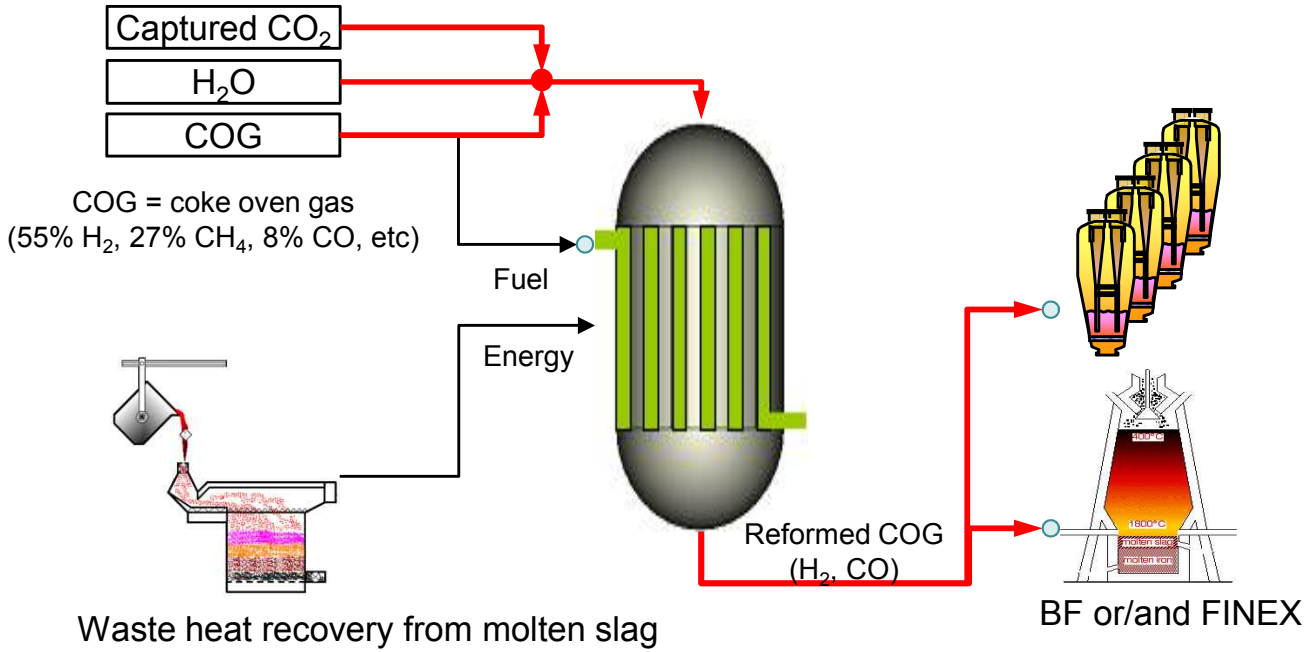
Dry ice

CO_2 Conversion using COG Reforming (I) : Concept/Feature

☐ Background

-Need for the conversion of capture CO_2 and the utilization in steel industry

☐ Steel-industry-specific CO_2 conversion and utilization



[COG reforming]

: $CH_4 + xH_2O + yCO_2 \rightarrow cH_2 + dCO$

Reduce coke consumption in iron-making process !!

[Conceptual scheme for production and utilization of the reducing gas in the steel process]

○ Mass production of the H_2 and/or CO rich gases by using COG reforming with steam and CO_2

- Require highly coking-resistant catalyst for the COG reforming
- Require optimization of reaction condition, heat integration, and scale-up by using reactor modeling

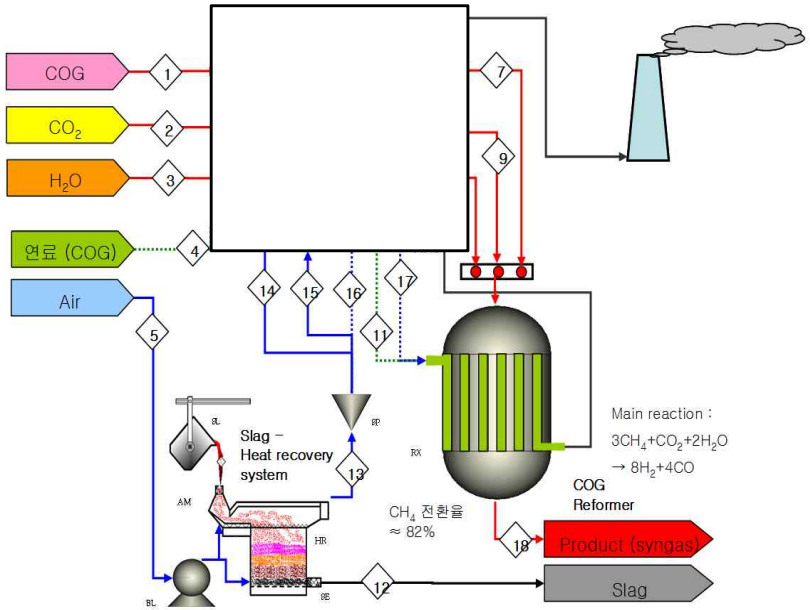
CO_2 Conversion using COG Reforming (II): Milestones

☐ R&D History/Plan

- Lab-scale research (2009~2011): Development of RIST catalysts with high activity over COG reforming with CO_2
  → Higher CH_4 conversion compared with commercial catalysts by 15%
- Pilot plant research (2012 - 2014): 50 Nm^3-(H_2+CO)/hr
  - The conceptual design has been carried out (- 2012)
  - The pilot plant construction is on-going (Feb. 2013-)
- CFD model development and case study to inject the reducing gas into blast furnace (not included in this PT)

☐ Pilot Plant Spec.

Item	Spec.
Feed Gas	- Simulated COG (Coke Oven Gas) - CO_2 & Steam
Reforming Catalyst	Ni-based catalyst
Product	~ 50 Nm^3-(H_2+CO)/hr
Conc. H_2 + CO	> 85 %



[Conceptual Design]

☐ Further Improvements

- Development of enhanced catalysts with high coking resistance
- Optimization and scale-up

Heat Recovery from Molten Steelmaking Slag (I)

Overview

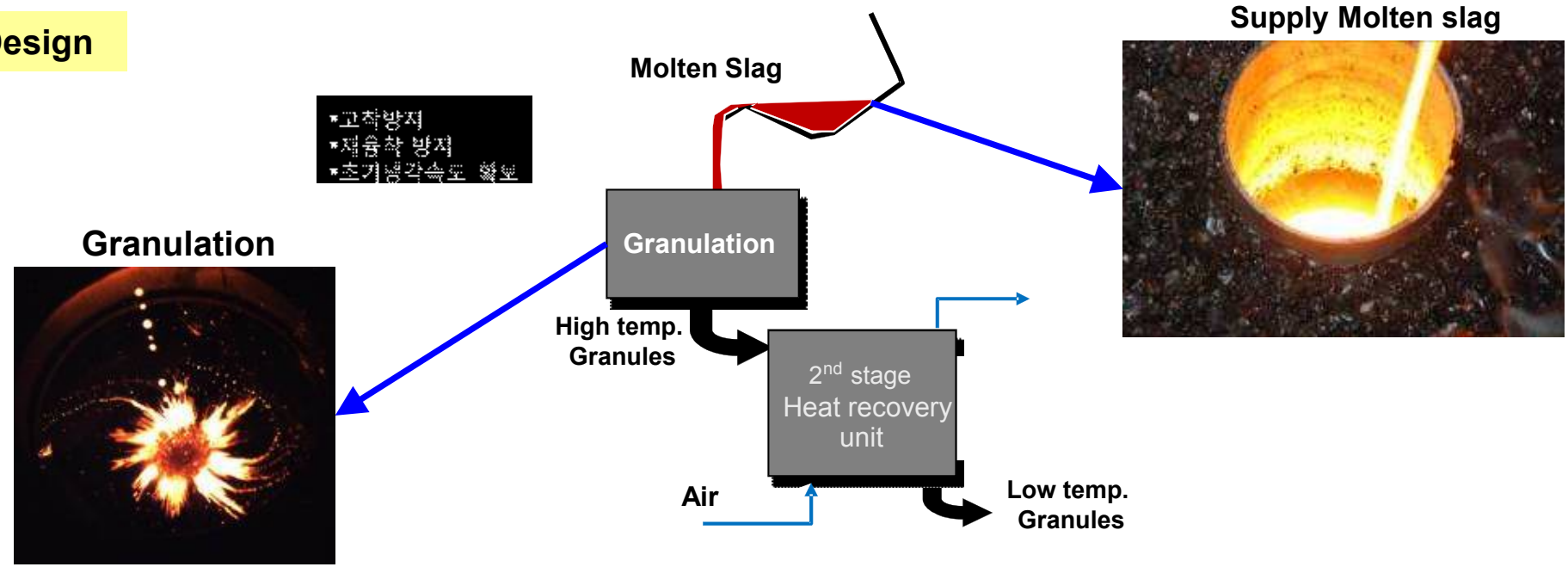
Development of heat recovery technology for the high temperature molten slag
- key issues: dry granulation and fast cooling of molten slag

Design Basic

Heat recovery ratio	> 50%
Target of recovery temperature	> 500 ℃
Final process scale	180 t-slag/h,unit

Heat recovery ratio (%) = Recovered heat by air / Molten slag heat capacity X 100

Conceptual Design



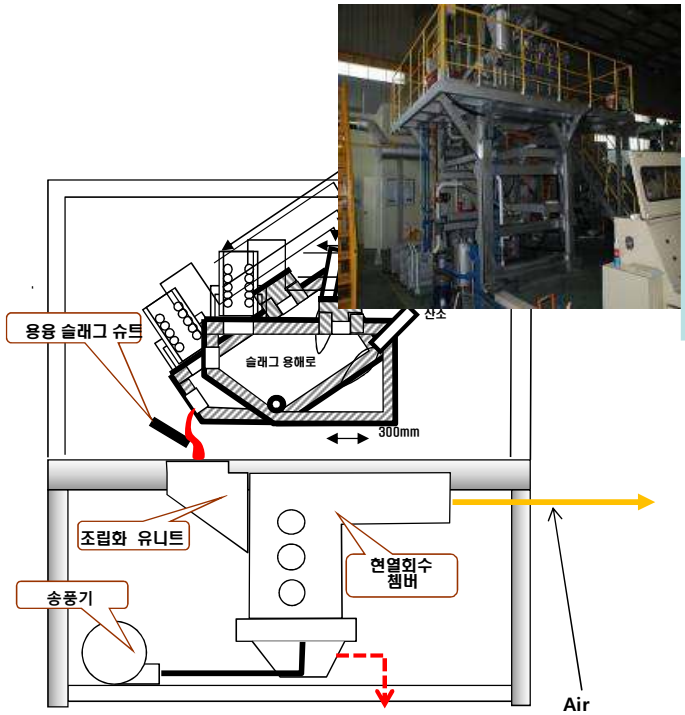
Application

Generation of power or steam by rapid cooling of slag particles

Heat Recovery from Molten Steelmaking Slag (II)

☐ R&D Activities & Schedule

(2009~2011)



< Lab-scale facility, 0.2 t-slag/h >

- Designed and installed a system for dry granulation and heat recovery
- Performance test of the equipment
- Recovery ~ 50%

(2012-2013)

< Pilot-scale facility, 2 t-slag/h >

- On-site pilot test at POSCO
- Target: Basic data for commercial scale-up

(2014 -)

< Demo facility, 30 t-slag/h >

- Commercial recovery system and its integration with CO_2 conversion unit

❖ CCU R&D topics at RIST

Major R&D Topics related to CCU technology and carbon emission reduction

- **CO_2 capture and utilization technology in iron and steel industry**
  - CO_2 Capture
  - Waste Heat Recovery from flue gas and molten steelmaking slag
  - CO_2 Utilization

- **Power generation from waste heat**
- **Restoration of coastal environments by steel-making slag**
- **Development of novel process for the synthesis of DMC**
- **Biodiesel production from sewage sludge & microalgae**

Conclusion

□ **In Korea, CO_2 utilization rather than storage is a "must" considering the geological and industrial environments.**

□ **POSCO desperately needs to reduce CO_2 emissions.**

- National emissions trading program will begin at 2015.
- Steel industry-specific CO_2 reduction routes are being investigated.

□ **A concept of CO_2 capture and utilization within the steel industry boundary.**

- The integrated concept of capturing CO_2 (using AA), its conversion into reducing gases (by COG reforming), and injection into BF is being studied.
- The pilot plants are operating at the lab or on-site separately.


Thank you