RITE
Research Institute of Innovative Technology for the Earth

UNFCCC-Climate Technology Centre and Network (CTCN) Technology Assistance Project

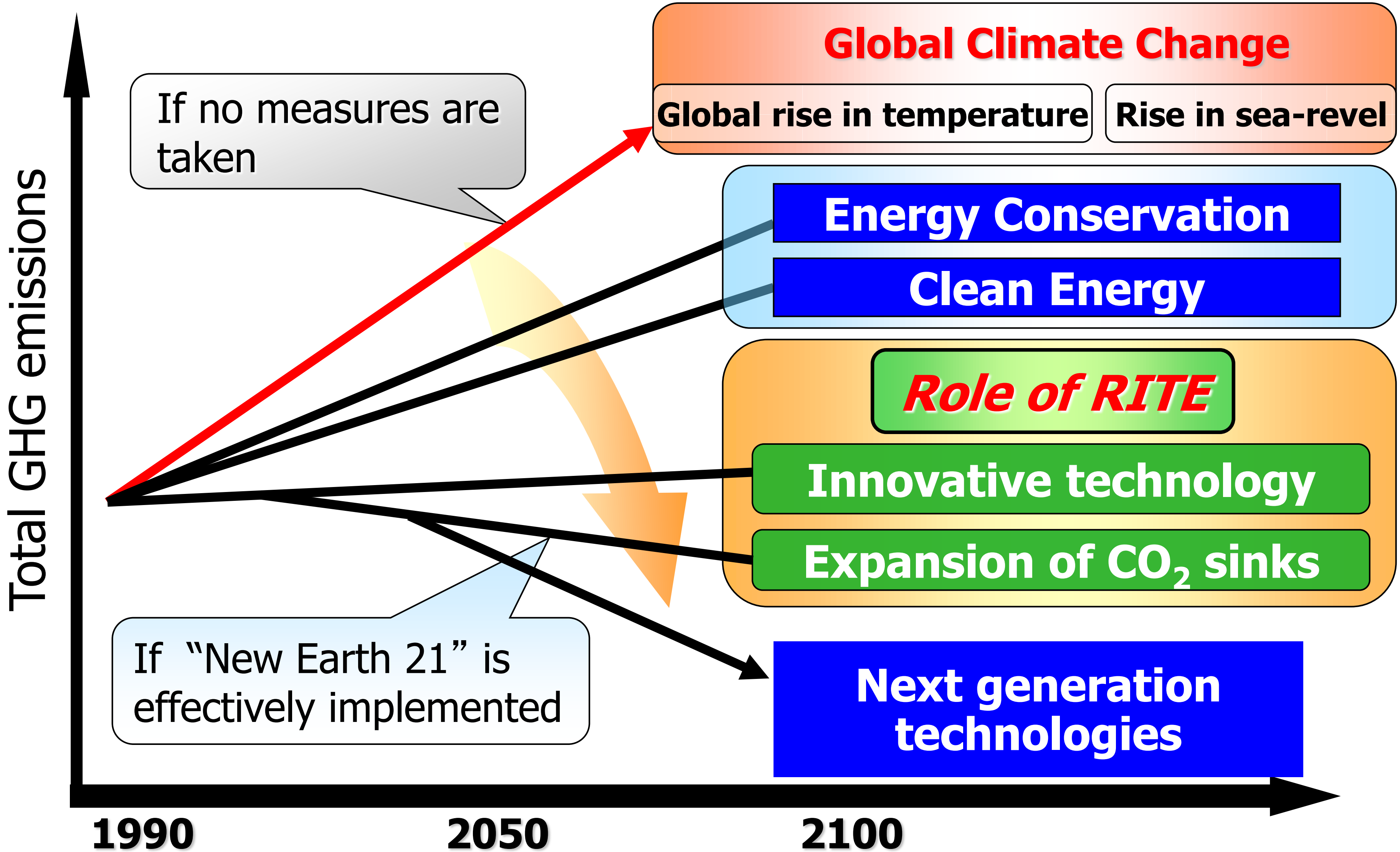
Feasibility Study on Introducing a Hybrid GHG Reduction Technology for the Cement Sector in South Africa

Research Institute of Innovative Technology for the Earth (RITE)

February 2017

1. "New Earth 21": Earth Regeneration Plan

proposed by Japanese government in 1990 G7 summit



1.1 Profile of RITE

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- Objective : R&D of industrial technologies that contribute to the conservation of the global environment and the progress of the world economy
- Establishment : July 1990 (Supported by MITI, local governments, academic circles and industries)
- Location : Kansai Science City
- Activities : Development of innovative environmental technology
  Expansion of CO_2 sinks
- Staffs : 168 (April 2015)
- Annual budget : Approx. 2.4 billion JPY (20M US$)

1.2 Focuses of RITE Key Activities

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CCS: Carbon dioxide Capture and Storage

- Technologies for separating/capturing CO_2 emissions from major emitters
- Geological and ocean storage or sequestration of CO_2

Development of Hydrogen Energy Carrier

Innovative bio-refinery technology

- Production of bio-fuels from cellulose
- Production of chemicals from cellulose
- Technology for large-scale CO_2 fixation using high-performance plants

Proposal of modeling-based global warming strategies for the near to distant future

1.3 Focuses of RITE Key Activities

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- Technological development for preventing global warming
  - ◆CCS: Carbon dioxide Capture and Storage
    - ▪Technologies for separating/capturing CO_2 emissions from major emitters
    - ▪Geological and ocean storage/sequestration of CO_2
  - ◆Innovative bio-refinery technology
    - ▪Production of bio-fuels from cellulose
    - ▪Production of chemicals from cellulose
    - ▪Technology for large-scale CO_2 fixation using high-performance plants
- Support policymaking by Japan and other countries
  - ◆ Proposal of modeling-based global warming strategies for the near to distant future

2. Climate Technology Centre & Network（CTCN)

CTCN was initiated at COP16(Cancun) and the network was established at COP18 (Doha)

Hosted by UNEP and UNIDO, the CTCN is the UNFCCC's technology mechanism

(i)to provide technical assistance(TA) to accelerate the technology transfer;

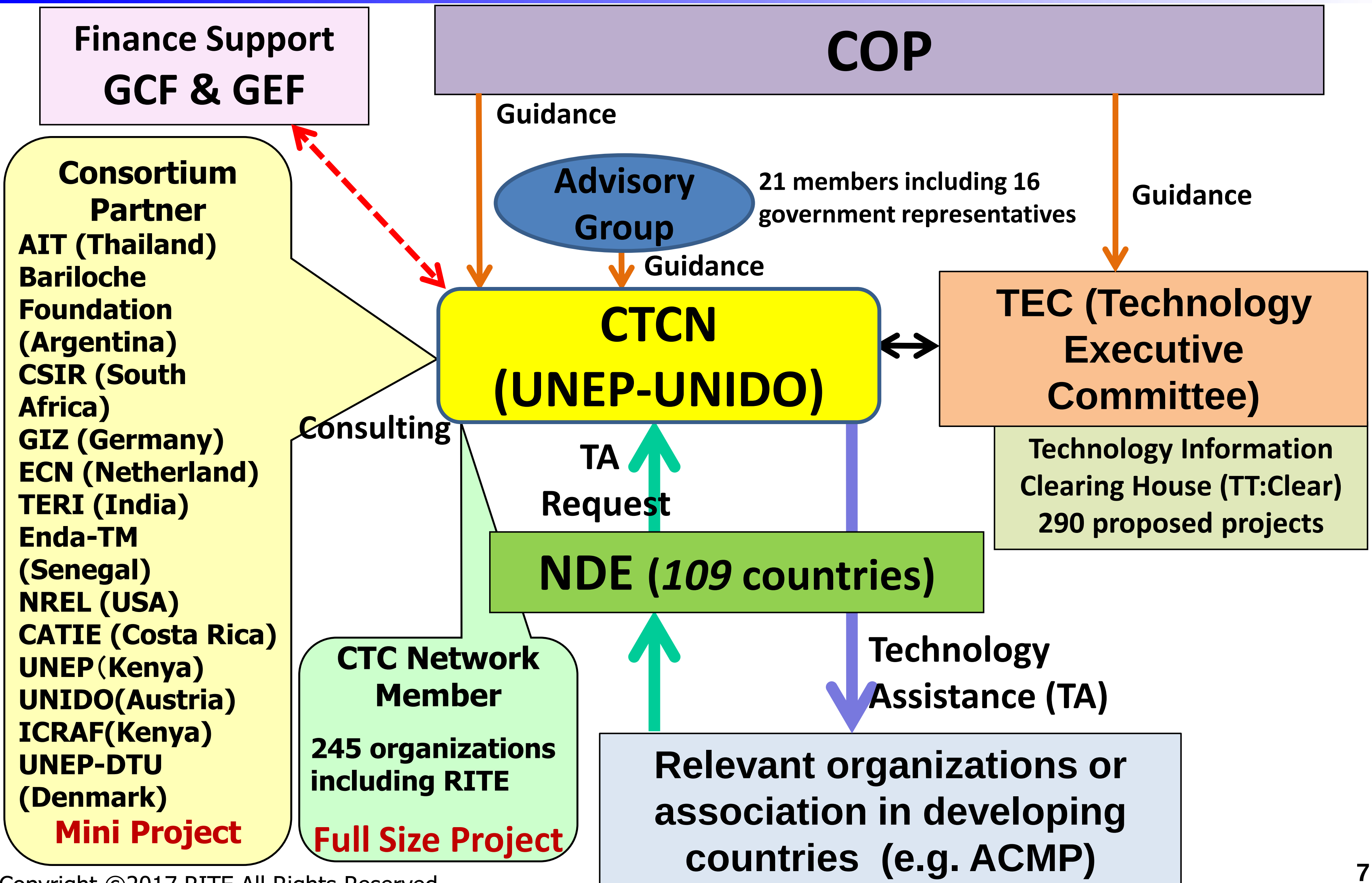
(ii)to disseminate information and knowledge on climate technologies;

and

(iii) to become a hub of collaboration among climate technology stakeholders.

https://www.ctc-n.org/

2.1 CTCN and Network



2.2 TA Project Outline

1. Title :	• Substantial GHG emissions reduction in the cement industry by using waste heat recovery combined with mineral carbon capture and utilization
2. Purpose:	• To estimate significant GHG emissions reduction from the cement sector by using carbonation technique with waste concretes and concrete sludge • To find appropriate and marketable means to reuse byproducts from the carbonation process and estimate GHG abatement cost
3. FS terms:	One Year (December 28,2016 - December 28, 2017)
4. Members:	• RITE (CTC network member, Japan) • ACMP(key representative, RSA) • Local Partners: ACMP member company/ies, Concrete product manufacturer(s), DEA (Chemical and Waste Branch/Climate Change Branch) and South Africa National Energy Department Institute (SANEDI) • MCC Expert: Tohoku University • Cement & Concrete Experts: Taiheiyo Engineering Corporation and NIPPON Concrete Industries Co., Ltd. • Finance Expert: Mitsubishi UFJ Morgan Stanley Securities Co., Ltd.

2.3 Technology Concept : Waste Heat Recovery & Mineral Carbon Capture and Utilization(MCC&U)

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Resource Efficiency

Concrete Sludge

or

Concrete Wastes

or

Industrial Wastes containing Alkali Earth Metal (e.g. Blast Furnace Slugs, etc.)

Energy Conservation

Hybrid low carbon technology

GHG reduction due to Carbon mineralization

MCC&U plant (reactor)

Waste Heat Recovery

CO_2-rich Exhaust Gas from Cement Kiln

$CaCO_3$

Resource Efficiency

Reuse as construction materials, painting, glass, ceramics, paper, rubber, resin, asphalt filler, food, pharmaceutical , colorant, etc.

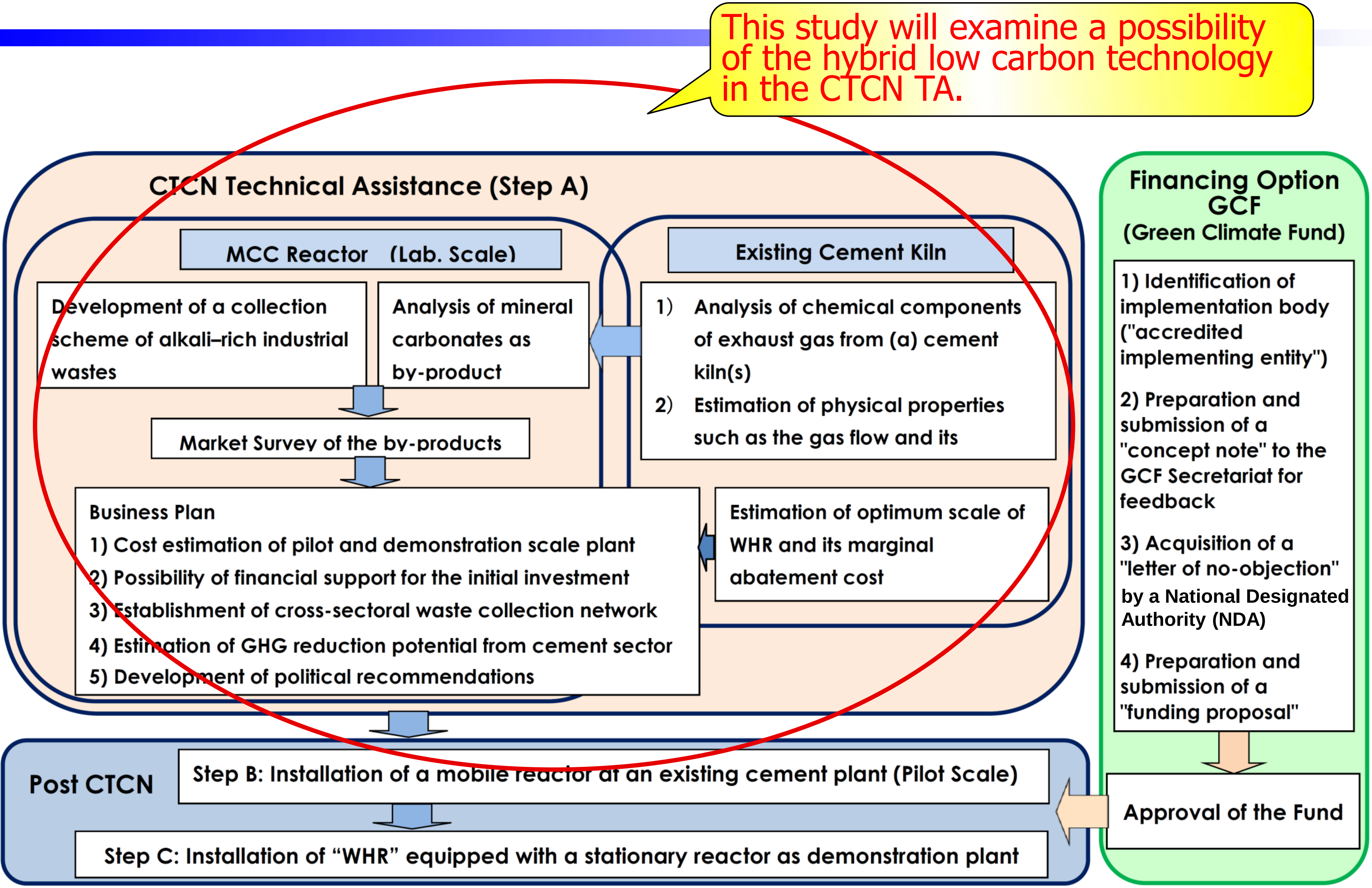
Removal of toxic materials from wastewater and soil, e.g. phosphorus and arsenic and reuse the materials

Remediation Agents: Adsorbents/Neutralizer

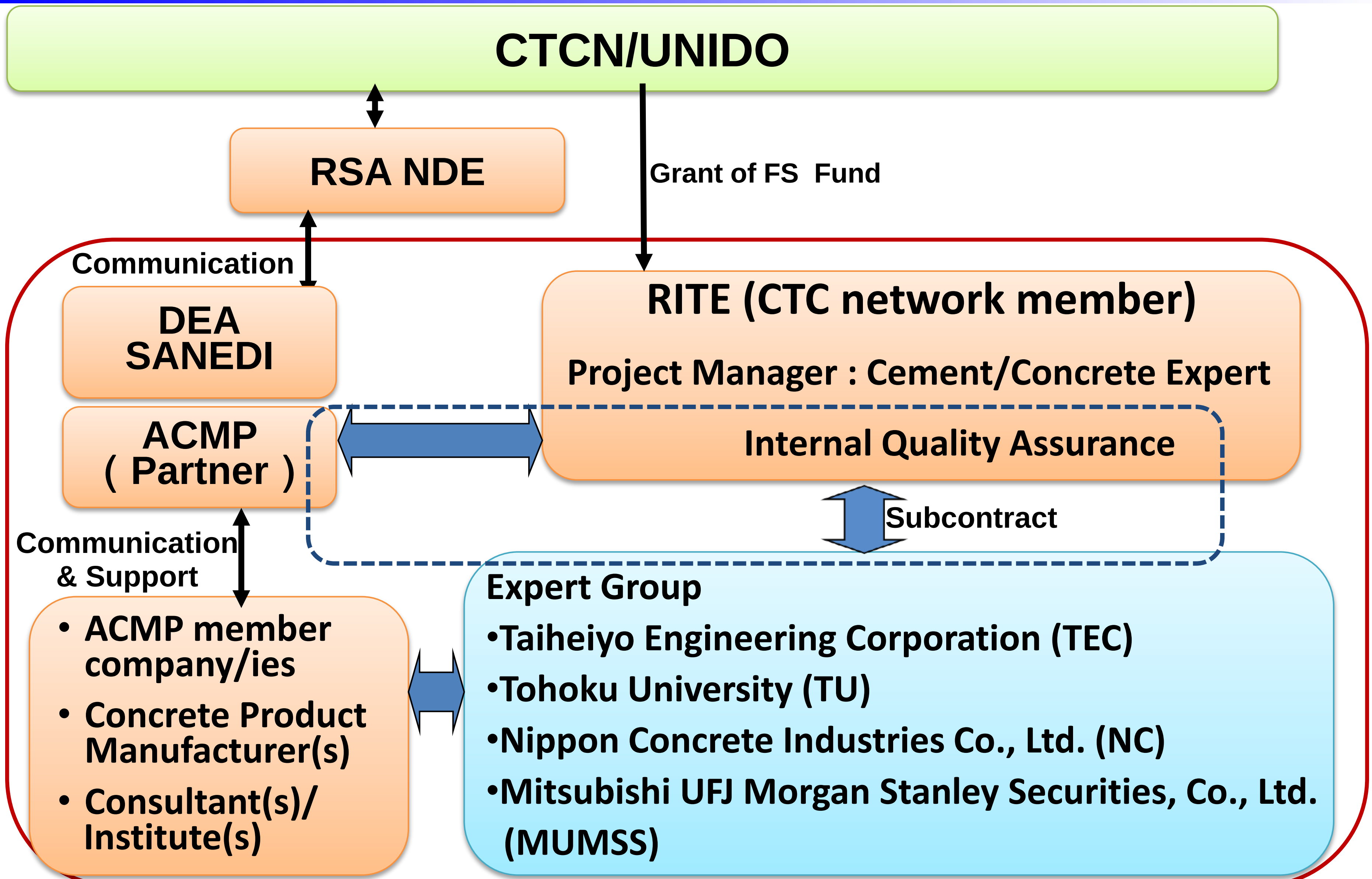
Resource Efficiency

Step A CTCN Technical Assistance

2.4 Image of Overall Project Flow

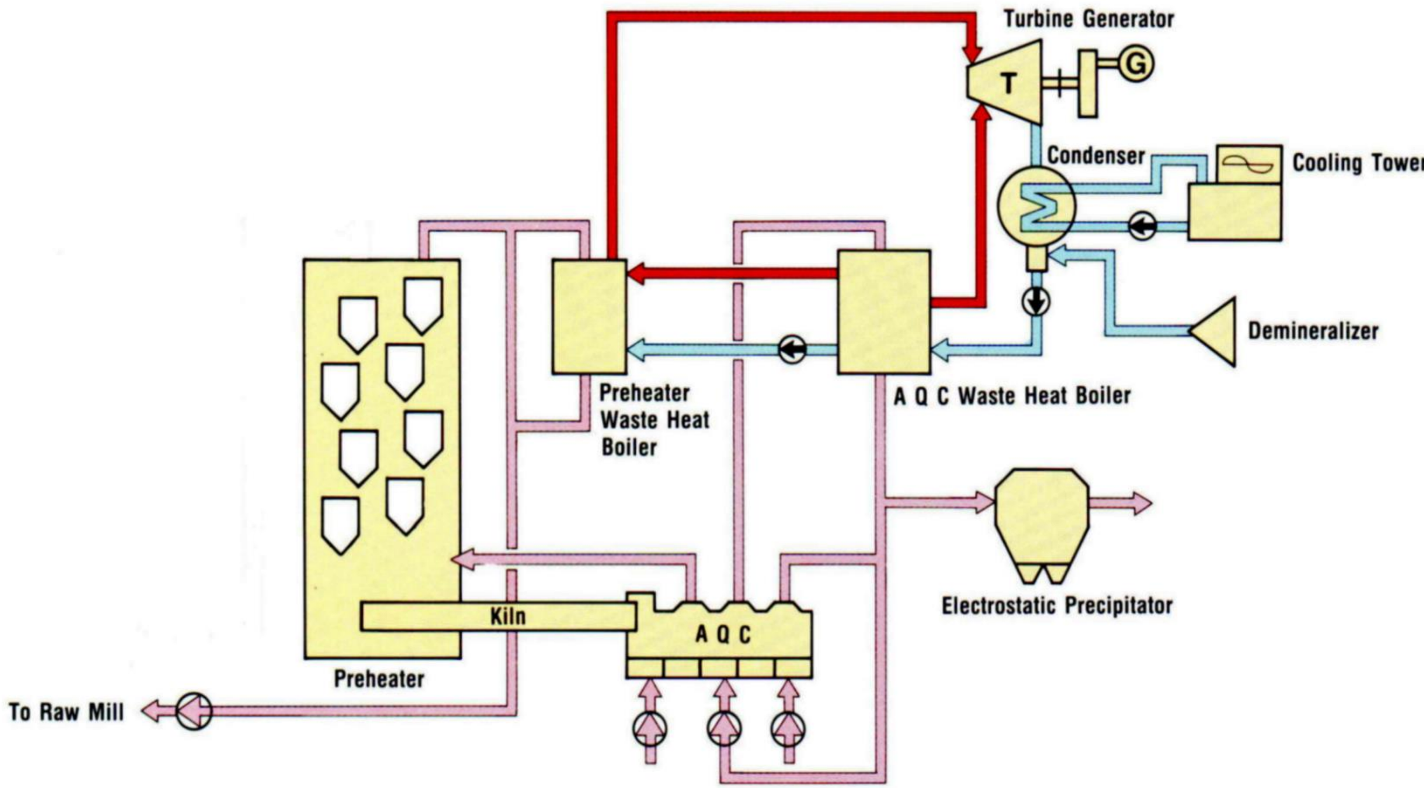


2.5 TA Project Framework



3. WHR: Waste Heat Recovery Power Generation

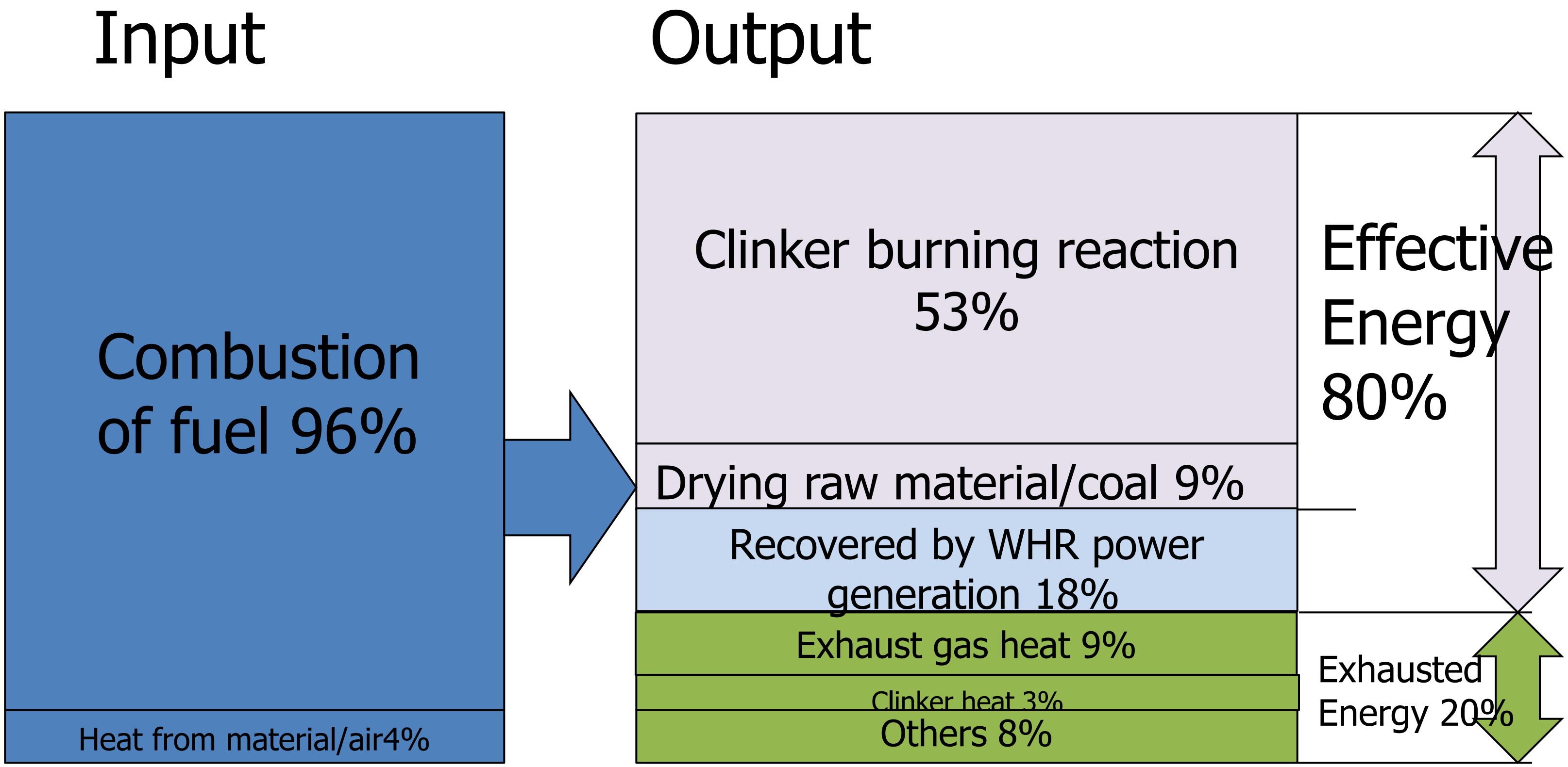
- Steam is generated at waste heat boilers by utilizing waste heat from preheater and clinker cooler in cement manufacturing system.
- Generated steam is introduced to turbine generator to generate electricity.
- Around 1/3 of necessary power can be generated by WHR.



Source: Taiheiyo engineering Corporation

3.1 Heat efficiency of WHR

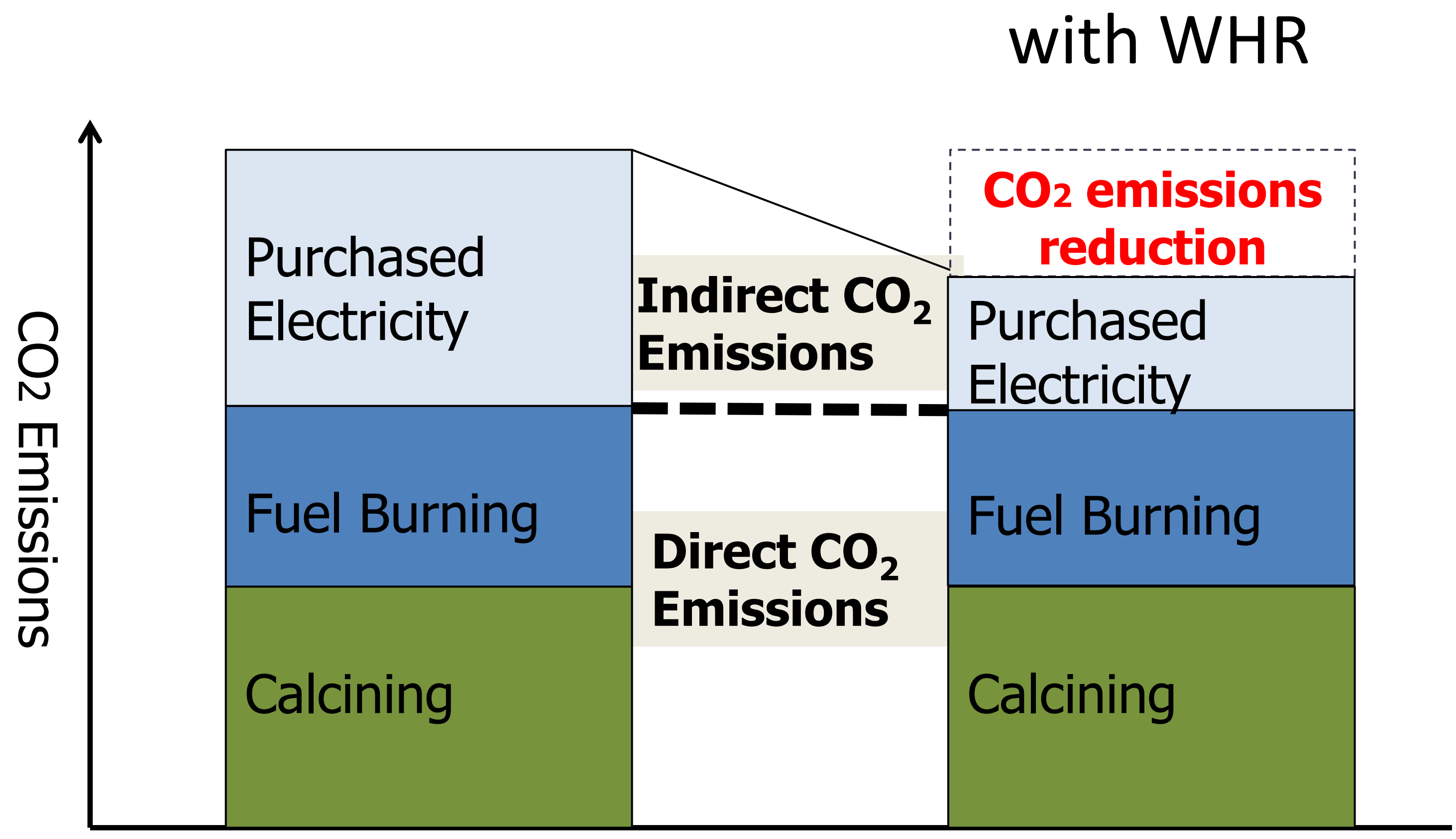
Heat utilization in Cement Plant (Rotary kiln)



18% of input energy can be utilized with WHR

Source: Taiheiyo engineering Corporation

3.2 CO_2 emissions before/after WHR



Source: Taiheiyo engineering Corporation

3.3 Features of WHR on Cement Manufacturing

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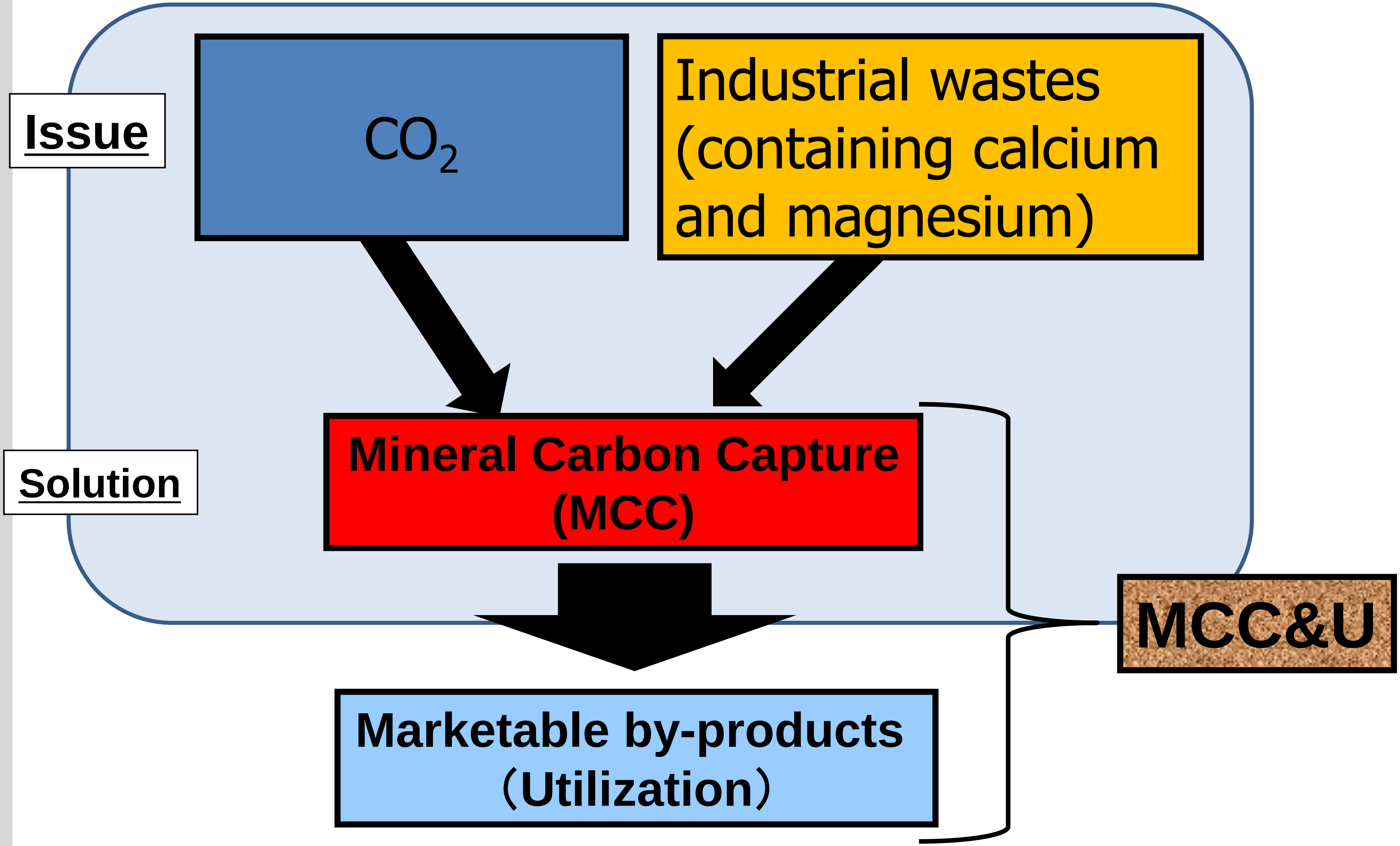
- Substantial **CO_2 emissions reduction** can be achieved
- Considerable amount of **power** can be utilized for the manufacturing
- **Electricity supply** shortage can be relieved
- Help the **South African economy to develop** while protecting environment

Source: Taiheiyo engineering Corporation

4. Why MCC&U ?



Source: Nippon Concrete Industries Co., Ltd.

Before concrete sludge is solidified, solid cake is separated from the sludge. "Solid cake" is disposed to landfill sites it's while the "liquid portion" is neutralized and then discharged to sewage or river.

Generation from formwork →

Storage with agitation →

Filtration →

フィルタープレスしたスラッジ（含水率 25～30%）

→ **Landfill Site**

Neutralization

→ **Sewage or River**

Photo: Nippon Concrete Industries Co., Ltd.

- *Treatment cost is very expensive（50 ～100 USD/t）*

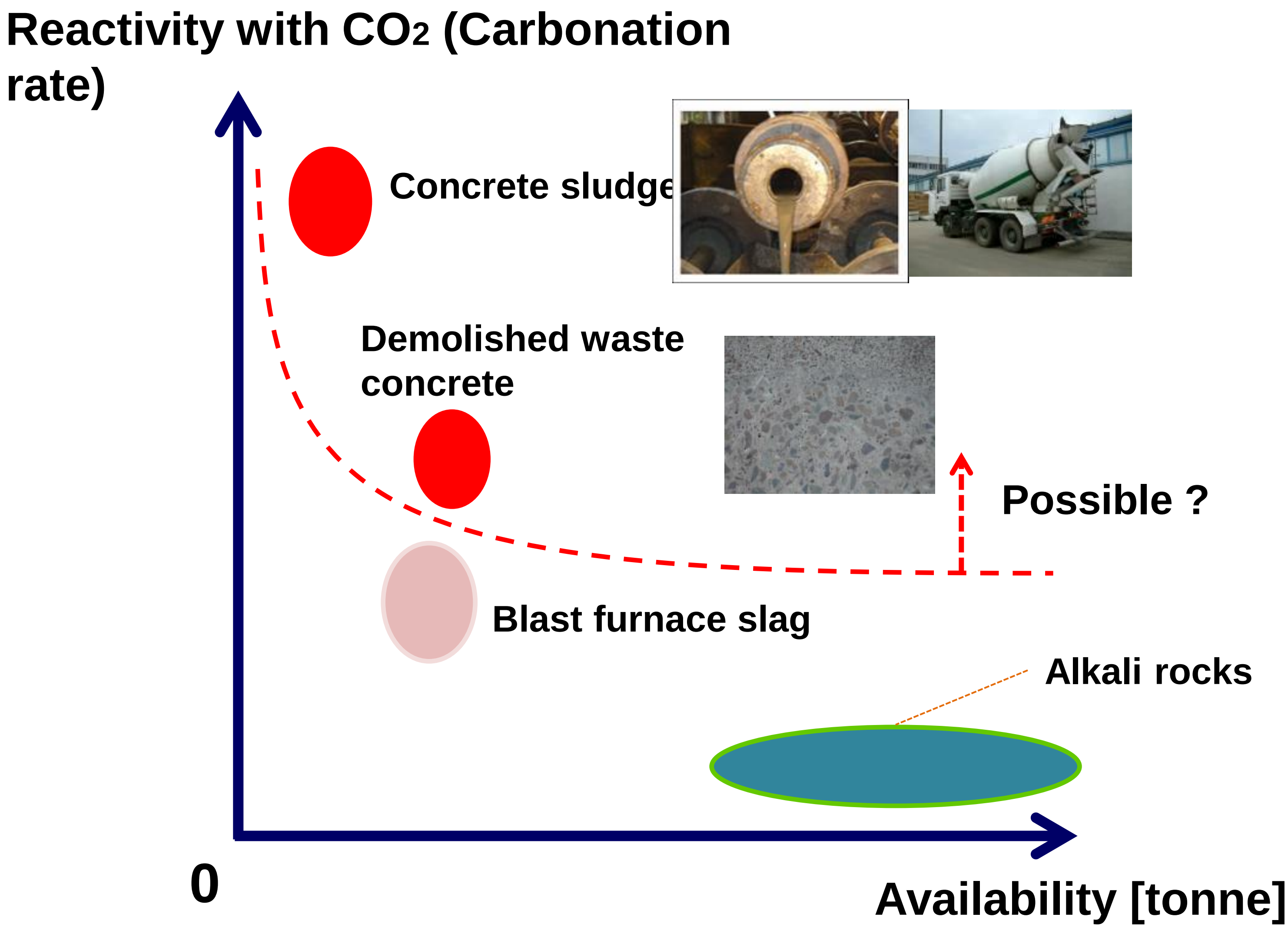
4.2 Carbon Mineralization

Ca and Mg from Concrete Sludge + $CO_2 \rightarrow$ Carbonates ($CaCO_3$, $MgCO_3$)

Advantages:

1. Huge potential for sequestration
2. Stable sequestration
3. Safety reaction process

4.3 Potential Alkaline Earth Metals from Wastes



Source: Tohoku University

4.4 Five Features of MCC&U

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- Innovative, yet easy to operate and safe to apply even in developing countries
- Possible for technology diffusion in developing countries
- Expecting substantial greenhouse gas emissions reduction by using concrete sludge and demolished waste concretes
- Small operation costs (=Total cost for the MCC operation - Sales value of by-products)
- High resource efficiency

Source: Nippon Concrete Industries Co., Ltd.

5. MCC: GHG Emissions Reduction

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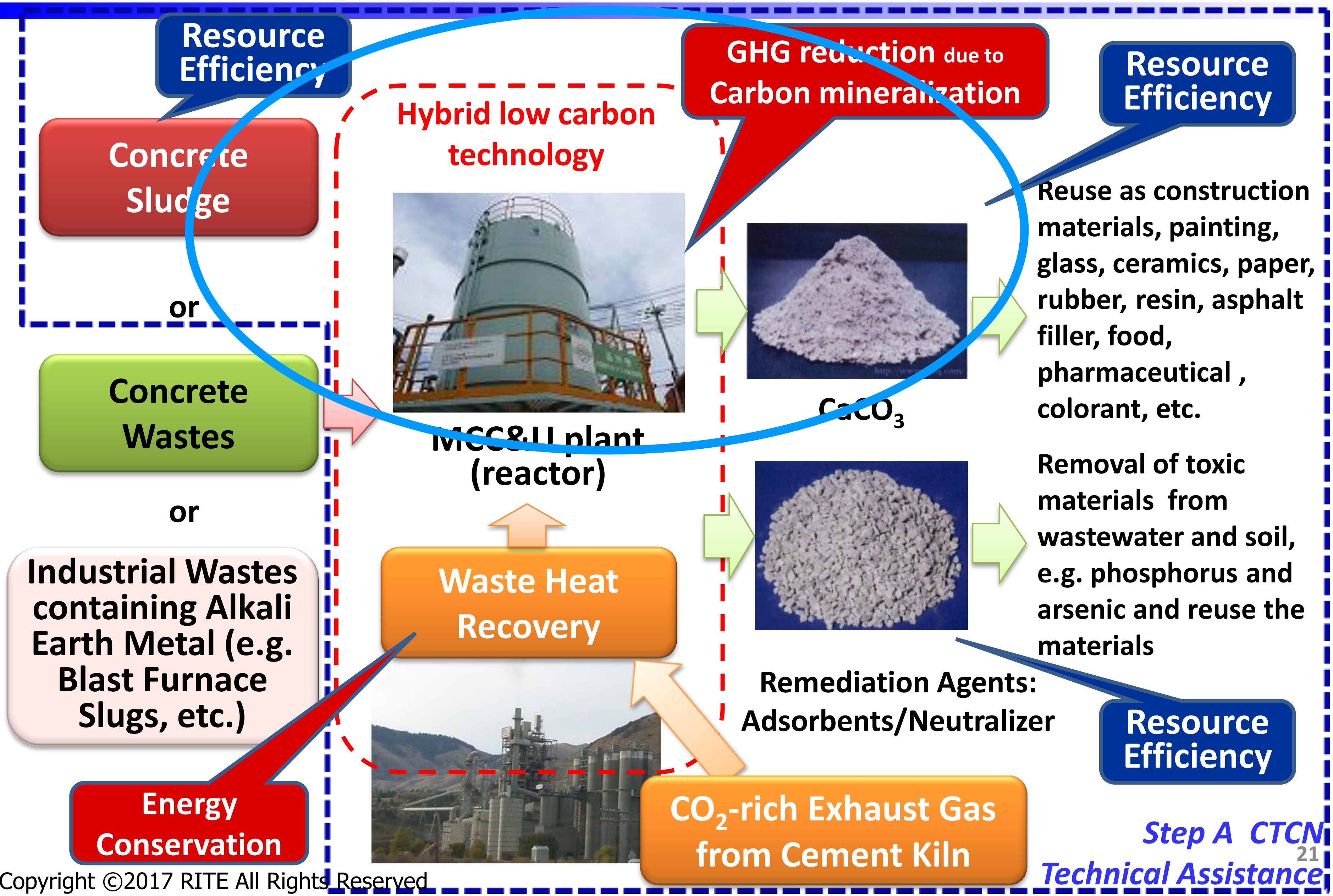

5.1 Process Flow of Carbon Mineralization Applied in Japan Utilizing Concrete Sludge

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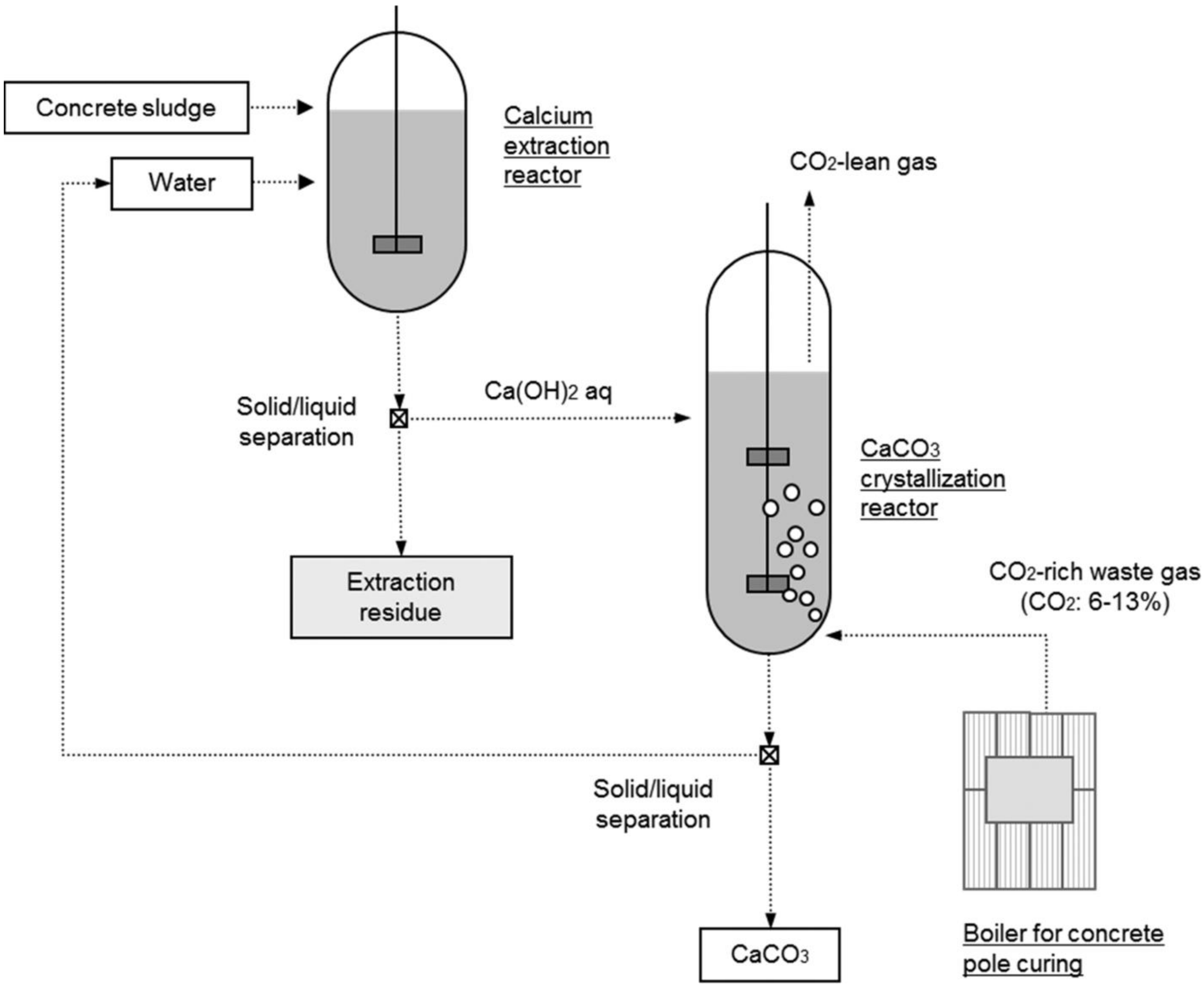


Source: Tohoku University

5.2 Development of MCC&U Plants in Japan

- **Bench scale plant (2009-)**

  2 Reactors (1 m^3) + 2 Storage tanks (1 m^3)

  equipped with pH meters, level meters, thermo meters, concentration meter for CO_2, pressure gauge for flue gas, etc.

- **Business operation plant (2013-)**

  Single Reactor (40 m^3)

Installation site:

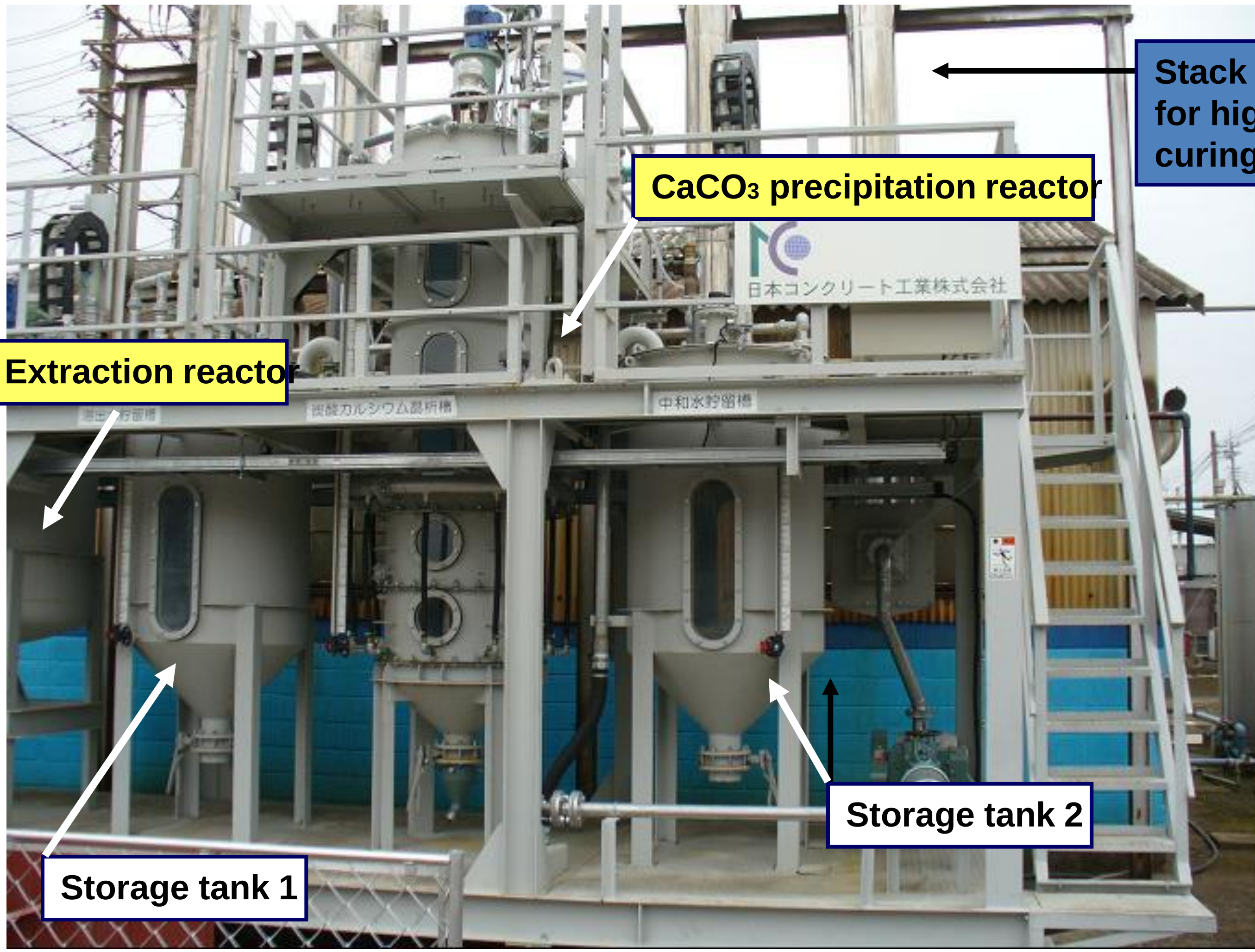
Kawashima 2nd factory of Nippon Concrete Industries Co. Ltd. which produces concrete poles by centrifugal molding






Photo: Nippon Concrete Industries Co., Ltd.

5.3 Outlook of the bench-scale plant



Completed in June 2009

Photo: Nippon Concrete Industries Co., Ltd.

5.4 Photos of Ca extraction experiments

Concrete sludge introduction

During agitation *

- **Calcium is extracted from concrete sludge into a liquid phase.**

After stopping agitation

After decantation

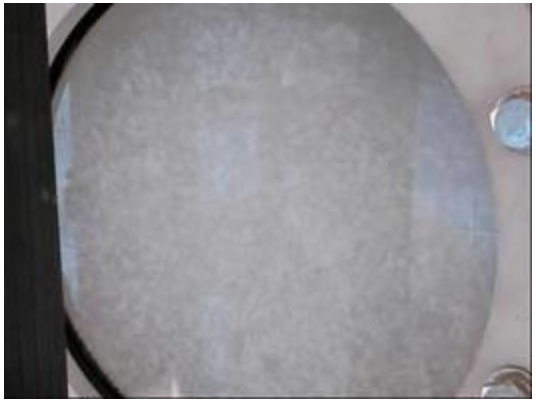
Photo: Nippon Concrete Industries Co., Ltd.

5.5 Photos of $CaCO_3$ precipitation experiments

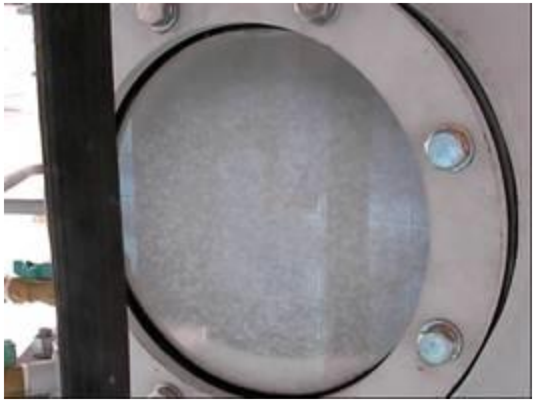
Before CO_2 bubbling

After CO_2 bubbling
Become clouded (After 1 min of CO_2 injection) *

- Due to the $CaCO_3$ precipitation



Crystal growth (After 3 min)



Gravitational sedimentation (After bubbling)

Photo: Nippon Concrete Industries Co., Ltd.

5.6 CaCO3 Produced from the Process

- **Purity: 99 wt% ～**
  Crystal shape: Calcite
  Particle size: 1 ～ 20 μm
  （Volume based laser scattering diameter）

- **The produced $CaCO_3$ can be reused as feedstock for non-energy use (example: choke, white line for ground.)**

*** image**

Source: Nippon Concrete Industries Co., Ltd.

5.7 Estimation of Carbon Captured Volume

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Ready mixed concrete plant

1,000,000 m^3-concrete/year

Waste generation ratio: 1%

10,000 m^3-concrete sludge/year
=23,500 tonne-concrete sludge/year
=3,000 tonne-Ca/year

2,000-4,000 tonne-CO_2/year

MCC&U plant

About 8,000 tonne-PAdeCS/year
4,000-8,000 tonne-$CaCO_3$/year
Recycled Aggregates

Concrete production plant

100,000 m^3-concrete/year

Waste generation ratio: 10%

10,000 m^3-concrete wastes/year
=23,500 tonne-concrete wastes/year
=3,000 tonne-Ca/year

2,000-4,000 tonne-CO_2/year

MCC&U plant

About 8,000 tonne-PAdeCS/year
4,000-8,000 tonne-$CaCO_3$/year
Recycled Aggregates

Source: Tohoku University

5.8 Various Waste vs. Performances

Alkali wastes	Amount (in Japan)	Potential of CO_2 sequestration (in Japan)	Byproducts	Advantages	Disadvantages	CO_2 sequestration cost
Concrete sludge	Moderate	Moderate	$CaCO_3$ and PAdeCS (Environmental purification agent)	Low impurities and High reactivity	-	Low
Concrete wastes	Large	Large	Mixture of $CaCO_3$ and PAdeCS	Low impurities	Relatively slow carbonation reaction rate	Moderate
Industrial wastes containing alkali earth metal (e.g. blast furnace slugs, etc.)	Large	Large	Depends on waste type	-	Impurities such as heavy metals	High

Source: Tohoku University

5.9 Various Waste vs. Carbon Captured Potentials

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Alkali wastes	Amount (in Japan)	Potential of CO2 sequestration (in Japan)	Byproducts	Advantages	Disadvantages
Concrete sludge	5 million tonnes / year	1 million tonnes / year	CaCO3 and PAdeCS (Environmental purification agent)	Low impurities and High reactivity	-
Concrete wastes	35 million tonnes / year	7 million tonnes / year	Mixture of CaCO3 and PAdeCS	Low impurities	Relatively slow carbonation reaction rate
Industrial wastes containing alkali earth metal (e.g. blast furnace slugs, etc.)	About 50 million tonnes / year	5 million tonnes / year	Depends on waste type	-	Impurities such as heavy metals

Source: Tohoku University

6. U: Sales of Marketable By-Products

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Resource Efficiency

Concrete Sludge

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Concrete Wastes

or

Industrial Wastes containing Alkali Earth Metal (e.g. Blast Furnace Slugs, etc.)

Energy Conservation

Hybrid low carbon technology

MCC&U plant (reactor)

Waste Heat Recovery

CO_2-rich Exhaust Gas from Cement Kiln

GHG reduction due to Carbon mineralization

$CaCO_3$

Resource Efficiency

Reuse as construction materials, painting, glass, ceramics, paper, rubber, resin, asphalt filler, food, pharmaceutical, colorant, etc.

Remediation Agents: Adsorbents/Neutralizer

Removal of toxic materials from wastewater and soil, e.g. phosphorus and arsenic and reuse the materials

Resource Efficiency

Step A CTCN Technical Assistance

6.1 By-Product (1): CaCO3

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Table 4 Characteristics of the produced $CaCO_3$

Item	Value	Method
Specific surface area by Blaine [cm^2/g]	3040	JIS R 5201-1997 (JIS, 1997)
BET specific surface area [m^2/g]	5.12	One point method by nitrogen adsorption
Residue on 45-μm sieve [wt%]	17.6	JCAS K-02-2004 (JCAS, 2004)
Residue on 74-μm sieve [wt%]	0.5	JIS A 5008-1995 (JIS, 1995)
Degree of whiteness [%]	92.6	Hunter brightness (JIS, 1961)
Methylene-blue adsorption amount [mg/g]	0.06	JCAS I-61-2008 (JCAS, 2008)

- **Purity of the produced $CaCO_3$ is over 97 wt%**

Source: Nippon Concrete Industries Co., Ltd.

6.2 Application of $CaCO_3$

Table(a). Applications and its functions

Application	Function
Plastic	Improving strength, stability, mobility and dispersibility and lowering costs
Rubber	Improving workability and lowering costs
Paint	Adjusting viscosity, paint workability and joint searing
Paper (filter)	Improving storage stability (alkalinize) and lowering costs
Paper (coating)	Improving printing quality
Agriculture	Applicable to agents for improving water-solubility of pesticide and soil conditioner

Table(b). Application and selling volume

Product			Selling volume (2003) [10^3t]	Fraction [wt%]
Light CaCO3	Standard product	Paper	115	58.7
		Rubber	23	11.7
		Resin	18	9.2
		Paint	8	4.1
		Others	14	7.1
		Export	18	9.2
	colloidal product	Paper	73	34.8
		Rubber	55	26.2
		Resin	44	21.0
		Paint	10	4.8
		Others	9	4.2
		Export	19	9.0

Source: Nippon Concrete Industries Co., Ltd.

6.3 By-Product (2): PAdeCS

- **Feature of PAdeCS**
1. **Possible particle size adjustment**
2. **Decontamination agent（example: phosphorus and arsenic removal agent, neutralizer, etc.）**
3. **Low costs compared to conventional products**

- **Effective as phosphorus removal agent applied to:**
- **Small-scale purification-systems**
- **Rice washing wastewater rich in phosphorus (under consideration)**

Source: Nippon Concrete Industries Co., Ltd.

6.4 Business Operation Plant (since 2013)

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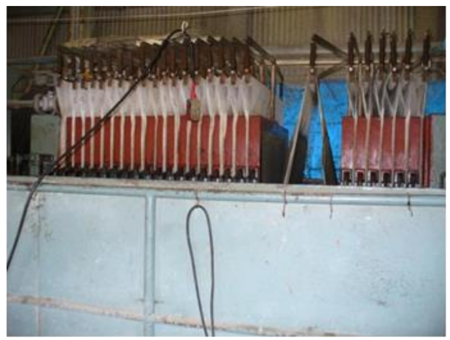
One of the first pilot-scale plants of a mineral carbonation process using alkali wastes.

Ca Extraction reactor (2000 t/year, 30 m^3)



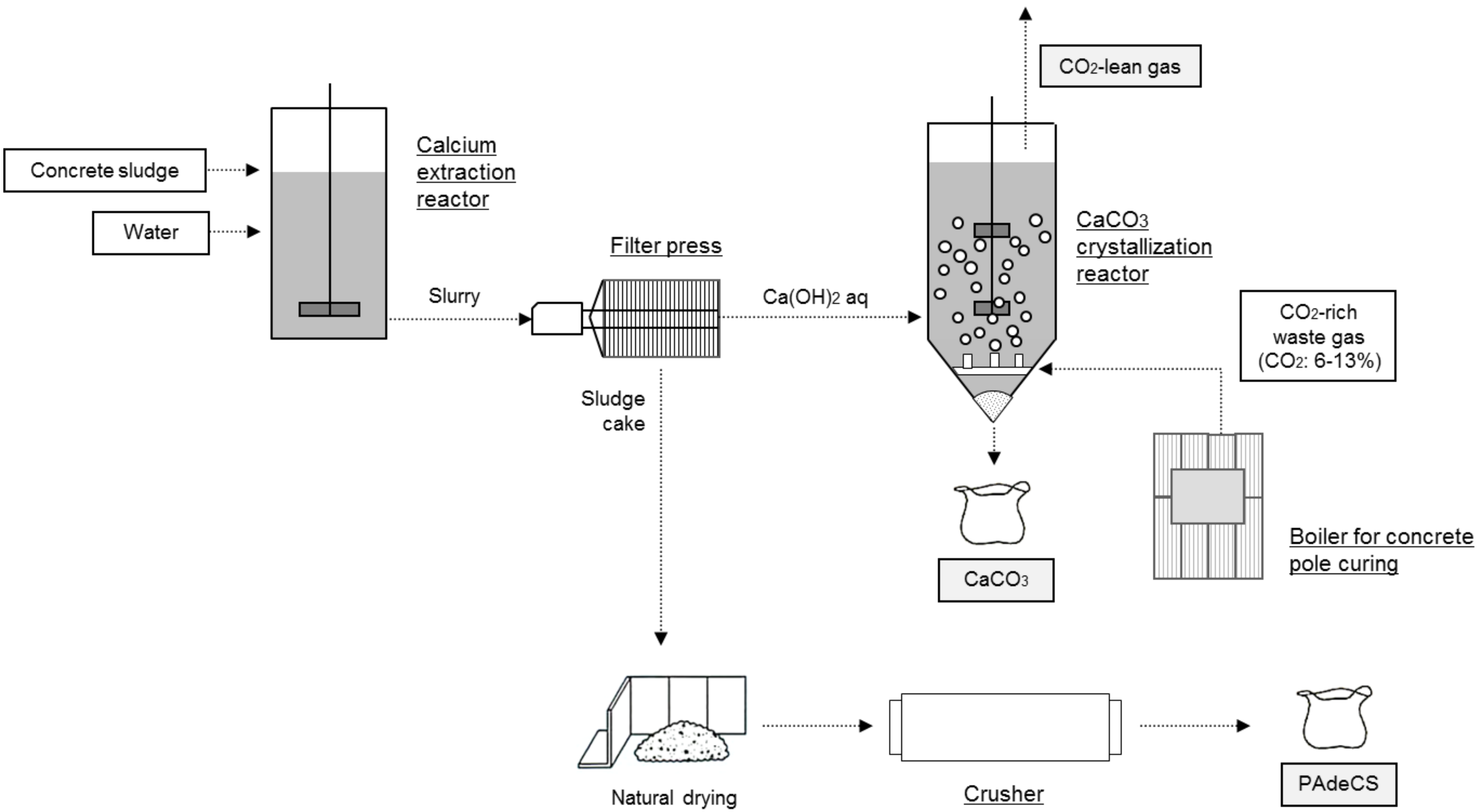
Filter press

$CaCO_3$ precipitation reactor (40 m^3)

Crusher

Photos & Source : Nippon Concrete Industries Co., Ltd.

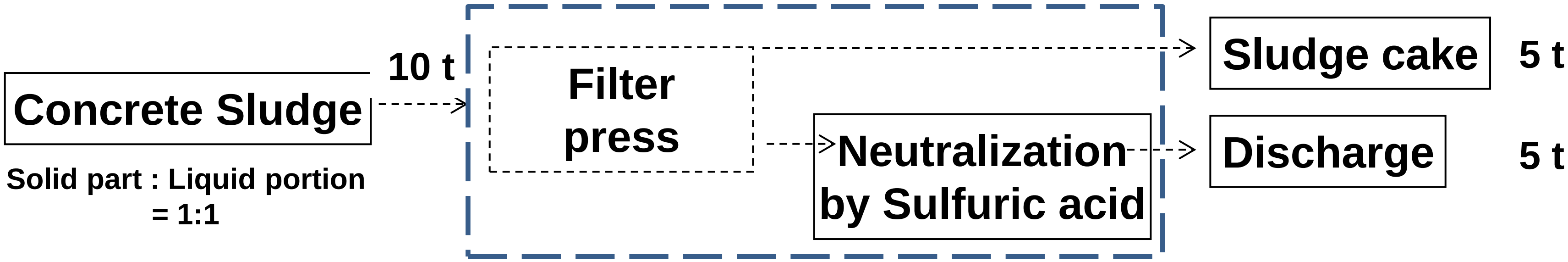
6.5 Process flow of the plant



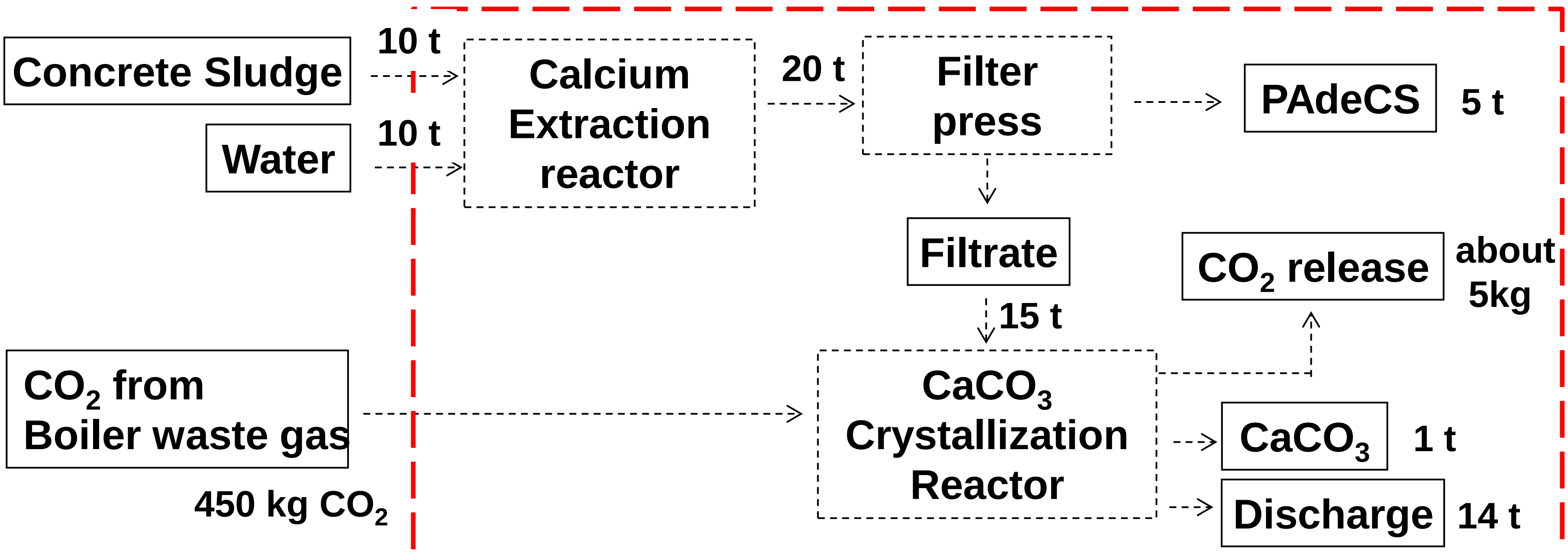
Source: Nippon Concrete Industries Co., Ltd.

6.6 Mass flow of the plant

➢ Conventional treatment process



➢ Business operation plant



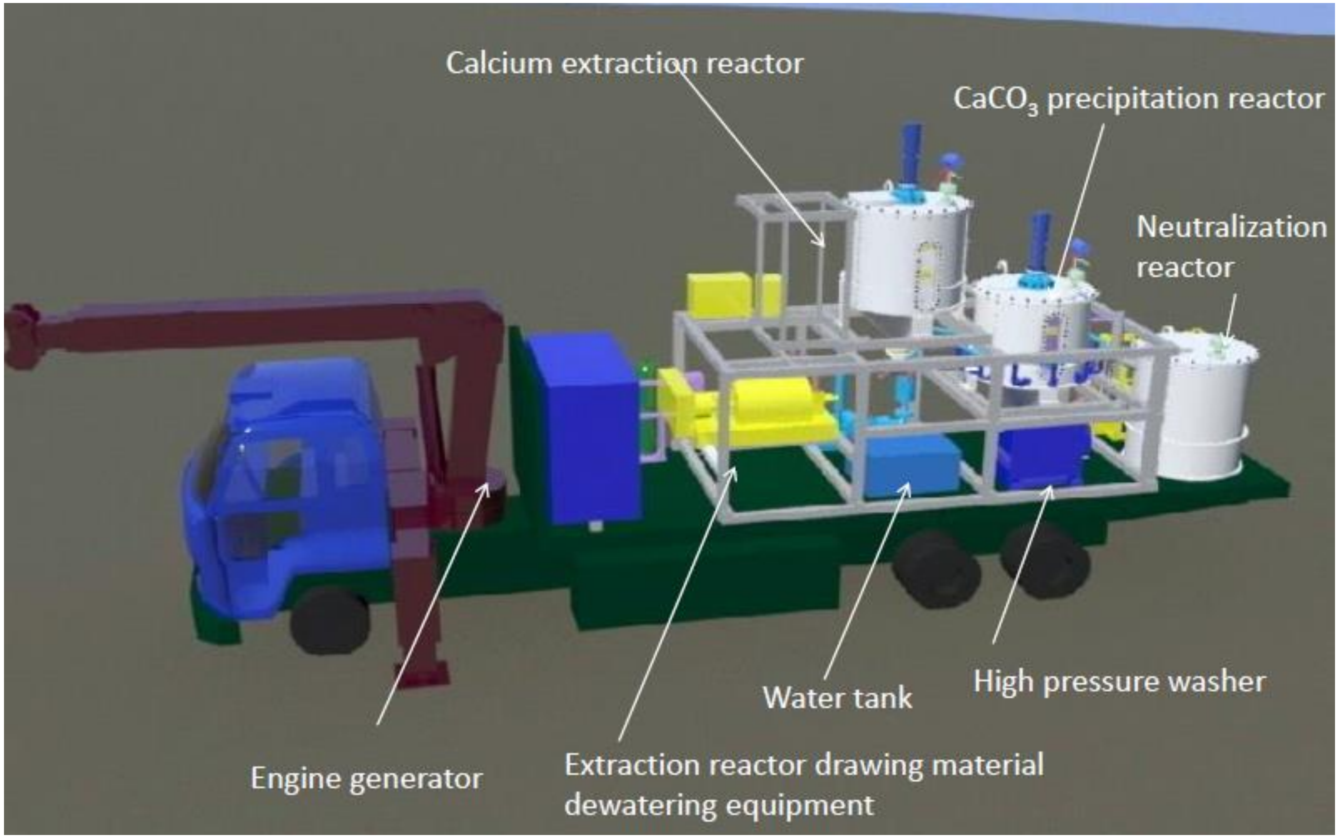
Source: Nippon Concrete Industries Co., Ltd.

7. Work Plan

Research item/Activity	Jan. - Mar.	Apr.- June	July – Sep.	Oct. – Dec.
	Sandton & Sites	Sandton & Sites	Sandton	Sandton & Pretoria
Activity 1. Identification and testing of the available alkali-rich industrial wastes and assessment of the MCC reaction				
Activity 1.1				
Activity 1.2				
Activity 1.3				
Activity 2. Assessment of the domestic market for the by-products				
Activity 2.1				
Activity 2.2				
Activity 3. Estimation of the GHG emissions reduction potential of WHR and MCC &U for the cement sector				
Activity 3.1 & Activity 3.2				
Activity 3.3 & Activity 3.4				
Activity 4 –Development of a business plan and project implementation recommendations				
Activity 4.1 & Activity 4.2				
Activity 4.3 & Activity 4.4				
Activity 5. Stakeholder meetings	Activity 5.1 Project introduction and preparation <February 2>	Activity 5.2 Report on 1.1 & 1.2 and preparation for 2 & 3	Activity 5.3 Report on 1.2 + interim report on 2.1, 2.2, 3.1 &3.2	Activity 5.4 Disseminate the findings of the business plan and the hybrid low carbon technology
Submission of Report to UNIDO	Inception Report	Progress Report		Final Activity Report

8. Post CTCN

Step B Image of proposed mobile bench-scale MCC&U reactor



Source: Nippon Concrete Industries Co., Ltd.

Step C WHR equipped with a stationary MCC&U reactor

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Thank you for your attention !

Contact to yoshito-izumi@rite.or.jp