Trends in Technologies for Utilizing CO_2 Derived from Thermal Power Plants and the Challenges of Applying them to the Civil Engineering Sector (Outline)

March 2024

The Task Force for the Research and Study of Civil Engineering Technologies for Utilizing CO_2 Derived from Thermal Power Plants, under the Subcommittee on New Technologies and Energy of the Energy Committee in the JSCE

Positioning of This Material

The Task Force for the Research and Study of Civil Engineering Technologies for Utilizing CO_2 Derived from Thermal Power Plants (commonly abbreviated the Carbon Recycle Task Force; referred to as the "CR Task Force" in this document) was established under the Subcommittee on New Technologies and Energy of the Energy Committee in the JSCE.

The purposes of the activities of the CR Task Force are threefold as shown below:

(1) Conduct research on civil engineering technologies that contribute to the dissemination and promotion of carbon recycling;

(2) Study future social systems, business models, and value chains; and

(3) Identify and organize technical challenges, as well as challenges related to systems, laws and regulations.

The CR Task Force carried out activities from July 2021 to September 2023 and published a report titled "Trends in Technologies for Utilizing CO_2 Derived from Thermal Power Plants and the Challenges of Applying them to the Civil Engineering Sector" (in Japanese).
https://committees.jsce.or.jp/enedobo0302/node/7

This material is the English translation of the composition of the CR Task Force, the table of contents of the report, the CO_2 countermeasure technologies related to the core content of the report (as mentioned in Item (1) above) in the concrete and cement sectors, and individual data on these technologies (Appendix) for the purpose of disseminating the outcomes of the task force's activities both domestically and internationally.

This material uses the same figure and table numbers as those in the report, and figures illustrating mechanisms are provided with reference page numbers from the report.

Composition of the CR Task Force

Classification	Name	Affiliation and title	Remarks
Secretary	Kinya Sakanishi	Senior Manager, Innovative Human Resources Department, the National Institute of Advanced Industrial Science and Technology	
Committee member and secretary	Tadashi Matsumoto	General Manager in Charge of the Domestic CCS Project Task, Corporate Planning & Administration Office, Corporate Planning & Administration Department, Electric Power Development Co., Ltd.	
Committee member	Tomoaki Oshiro	Power Generation and Operation Group Manager, Power Generation Department, Power Generation Division, the Okinawa Electric Power Company, Incorporated	Until June 2022
	Kaname Ishikawa	Power Generation and Operation Group Manager, Power Generation Department, Power Generation Division, the Okinawa Electric Power Company, Incorporated	From July 2022
	Noriharu Onishi	Senior Manager, Second Civil Engineering Marketing Department, Civil Engineering Division, Nishimatsu Construction Co., Ltd.	
	Hiroo Oyama	Manager, Project Promotion Department, Civil Engineering Management Division, Kajima Corporation	
	Seiji Kato	Chief Researcher, Civil Engineering Group, Power Technology Research Institute, Technology Development Division, Chubu Electric Power Co., Inc.	
	Ryoma Kitagaki	Associate Professor, Laboratory of Building Materials, Research Group of Structural Engineering and Materials, Division of Architecture, Faculty of Engineering, Hokkaido University	
	Chikao Sannou	General Manager, Civil Engineering Technology Team, Civil and Architectural Engineering Department, Hokuriku Electric Power Company	
	Takehiro Shibuya	Chief of Civil & Architectural Engineering Management Unit, Civil & Architectural Engineering Group, O&M E Operation Division, JERA Co., Inc.	
	Noriaki Shimizu	General Marketing Manager, Business Development & Marketing Division-Civil Engineering, Shimizu Corporation	Until March 2022
	Makoto Takagi	General Marketing Manager, Business Development & Marketing Division-Civil Engineering, Shimizu Corporation	From April 2022
	Akiro Shimota	Research Counselor, Meteorology and Fluid Science Division, Sustainable System Research Laboratory, Central Research Institute of Electric Power Industry	
	Takeshi Takagi	Deputy Chief, Civil and Architectural Engineering Department (Civil and Architectural Engineering Business), Tohoku Electric Power Co., Ltd.	
	Yuji Tsubota	Deputy Chief, Renewable Energy and Civil Engineering Management Group, Power Generation Division, the Chugoku Electric Power Co., Inc.	
	Yoshiyuki Matsumoto	Energy Business Development Department Manager, Business Development Division, Hazama Ando Corporation	
Observer	Hiroshi Tsuchiya	Head of Carbon Recycle Office, Commissioner's Secretariat, Agency for Natural Resources and Energy, the Ministry of Economy, Trade and Industry	Until June 2022
	Yumiko Hata	Director, Carbon Management Division, Natural Resources and Fuel Department, Agency for Natural Resources and Energy, the Ministry of Economy, Trade and Industry	From July 2022
Observer (Chairperson of the Subcommittee on New Technologies and Energy)	Yasuhide Yamada	Executive Officer (Environment and Energy), Corporate Planning Division, Shimizu Corporation	
Observer (Secretary of the Subcommittee on New Technologies and Energy)	Yohei Sumikawa	Team Leader, Planning Group, Civil & Architectural Engineering Management Office, Engineering Strategy Unit, Tokyo Electric Power Company Holdings, Inc.	Until August 2022
	Masayuki Masuda	Senior Researcher, Energy & Environment Division, R&D Department, TEPCO Research Institute, Tokyo Electric Power Company Holdings, Inc.	From June 2022

* The names, affiliations and titles of the committee members are based on those at the time of the 10th subcommittee meeting (September 28, 2023).
* When a committee member is replaced, the affiliation and title of the outgoing member are those at the time of the replacement, and the affiliation and title of the new member are as listed above.

Table of Contents of the Report (Main Text)

Trends in Technologies for Utilizing CO_2 Derived from Thermal Power Plants and the Challenges of Applying them to the Civil Engineering Sector

Chapter 3 CR-Related Civil Engineering Technologies

3.1 Technological Area of CR

3.1.1 Classification of CR Technologies

(1) Expected CO_2 capture methods
- a) Low CO_2 Concentration in the Atmosphere: Direct Air Capture (DAC)
- b) High CO_2 Concentration in Exhaust Gas: Carbon Capture (CC)

(2) Methods of storing and utilizing CO_2
- a) Simple storage of CO_2: Storage (S)
  Use of a storage device whose sole purpose is continuous management of the input and output of CO_2.
- b) Utilization associated with storage of CO_2: Utilization and Storage (US)
  A method that uses structures or structural members capable of providing additional services.

(3) Treatment of CO_2 after storage and utilization
- a) CO_2 can be released as a gas with the expectation that it will be recaptured.
  (Production of synthetic resins or bioethanol using CO_2)
- b) CO_2 can be fixed for a long period in one place while exerting functions beyond storage.
  (Incorporation into artificial minerals like cement and concrete, natural minerals like soil, or plants (e.g., wood and algae))

In the construction field: DAC + CC + US ⇨ DACCUS ⇨ CCUS

3.1.2 Positioning of Civil Engineering Technology

(1) DACCUS and CCUS

DACCUS	CCUS
DAC Coat and CCC (C^4S)	25 other technologies

(2) Comparison between DAC and CC

	DAC	CC
CO_2 concentration	Low concentration	High
Applies to	Atmosphere	Thermal power plant and other facilities
CO_2 fixation	Low	High

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(3) Evaluation method

Current method (in the report)	LCA
Net CO_2 emission reduction compared to the CO_2 emissions from conventional products with identical functions, excluding the shipping and transportation of the products.	Net CO_2 fixation in identical products, calculated by subtracting the CO_2 emissions during the production or treatment of the products from the amount of CO_2 fixed in the products.

- Decrease in CO_2 emission reduction due to the reduction in CO_2 emissions during the onshore transportation of products (influence of onshore transportation).
- In the cement and concrete sectors, calcium silicate and calcium aluminate consume a large quantity of CO_2 through CO_2 fixation, which leads to enhanced strength and durability of the concrete (technological innovation).
- Commercialization of CCUS products that can reduce CO_2 emissions as much as possible.

To continuously motivate ongoing efforts toward reducing CO_2 emissions, net CO_2 emission reductions from conventional products with identical functions, excluding shipping and transportation, have been established as an evaluation criterion.

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3.2 Technologies in the Concrete and Cement Sectors

3.2.1 Introduction of Domestic and Overseas Technologies

(1) Trends in CR overseas

Table 3.2-1 Selection of prospective candidate technologies for carbonate production

Evaluation criteria	1. Direct utilization of exhaust gas from thermal power plants	2. Development stage (maturity of technology)	3. Feasibility of the design of commercial scale plants	4. CO_2 emission reduction	5. Economic performance	6. Marketability	Rating
1. GreenOre	◎	○	◎	○	○	◎	12
2. O.C.O. Technology	○	◎	◎	○	○	◎	12
3. Blue Planet	◎	◎	○	△	△	△	7
4. Solidia	○	◎	◎	○	△	○	9
5. CarbonCure	○	◎	◎	△	○	○	9
6. Carbon Capture Machine	◎	△	○	△	△	△	4
7. Carbon Upcycling UCLA	◎	△	○	○	△	○	6
8. Mineral Carbonation	○	◎	○	△	△	○	6

Point allocation: ◎ Excellent = 3 points, ○ Good = 1 point, △ Normal or inferior = 0 points

Source: Summary of the “Feasibility Study on Overseas Carbon Recycle Technologies” for the Study on the Advancement of Overseas Coal Development under the 2019 Overseas Coal Development Support Project, 2020 by the Japan Organization for Metals and Energy Security (JOGMEC).

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(2) Domestic trends in CR (Pages 35 to 54 of the main text)

Table 3.2-2 List of CR technologies in Japan

No.	CO_2 countermeasure technologies	Company or organization that introduces the technology
(1)	CO_2-SUICOM	Kajima Corporation
(2)	CO_2-TriCOM	The Chugoku Electric Power Co., Inc.
(3)	DAC Coat	Shimizu Corporation
(4)	Concrete using carbonated recycled aggregate	Tokyo Electric Power Company Holdings, Inc.
(5)	CarbonCure	Mitsubishi Corporation
(6)	T-Carbon Mixing	Taisei Corporation
(7)	O.C.O Technology Limited	Kobelco Eco-Solutions Co., Ltd. and Mitsubishi Corporation
(8)	Blue Planet	Mitsubishi Corporation
(9)	CCC (C^4S Project)	The University of Tokyo and Hokkaido University
(10)(15)(24)(26)	T-*e*Concrete series	Taisei Corporation
(11)	Clean-Crete N	Obayashi Corporation
(12)	SUSMICS-C	Shimizu Corporation
(13)	LigninCrete	Obayashi Corporation
(14)	ECM Concrete	Kajima Corporation
(16)	Super Green Concrete	Maeda Corporation
(17)	LHC (Low Carbon High-performance Concrete)	Hazama Ando Corporation
(18)	BBFA High Strength Concrete	Hazama Ando Corporation
(19)	Ashcrete	Hazama Ando Corporation
(20)	Geopolymer (Geopoly)	Nishimatsu Construction Co., Ltd.
(21)	AAM Concrete	Nishimatsu Construction Co., Ltd.
(22)	Cast-in-place Geopolymer (PolymerCrete)	Obayashi Corporation
(23)	Sustain-Crete	Sumitomo Mitsui Construction Co., Ltd.
(25)	Clean-Crete	Obayashi Corporation
(27)	Slagrete	Toda Corporation

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- Classification of technologies related to CO_2 absorption and utilization (Page 38 of the main text)

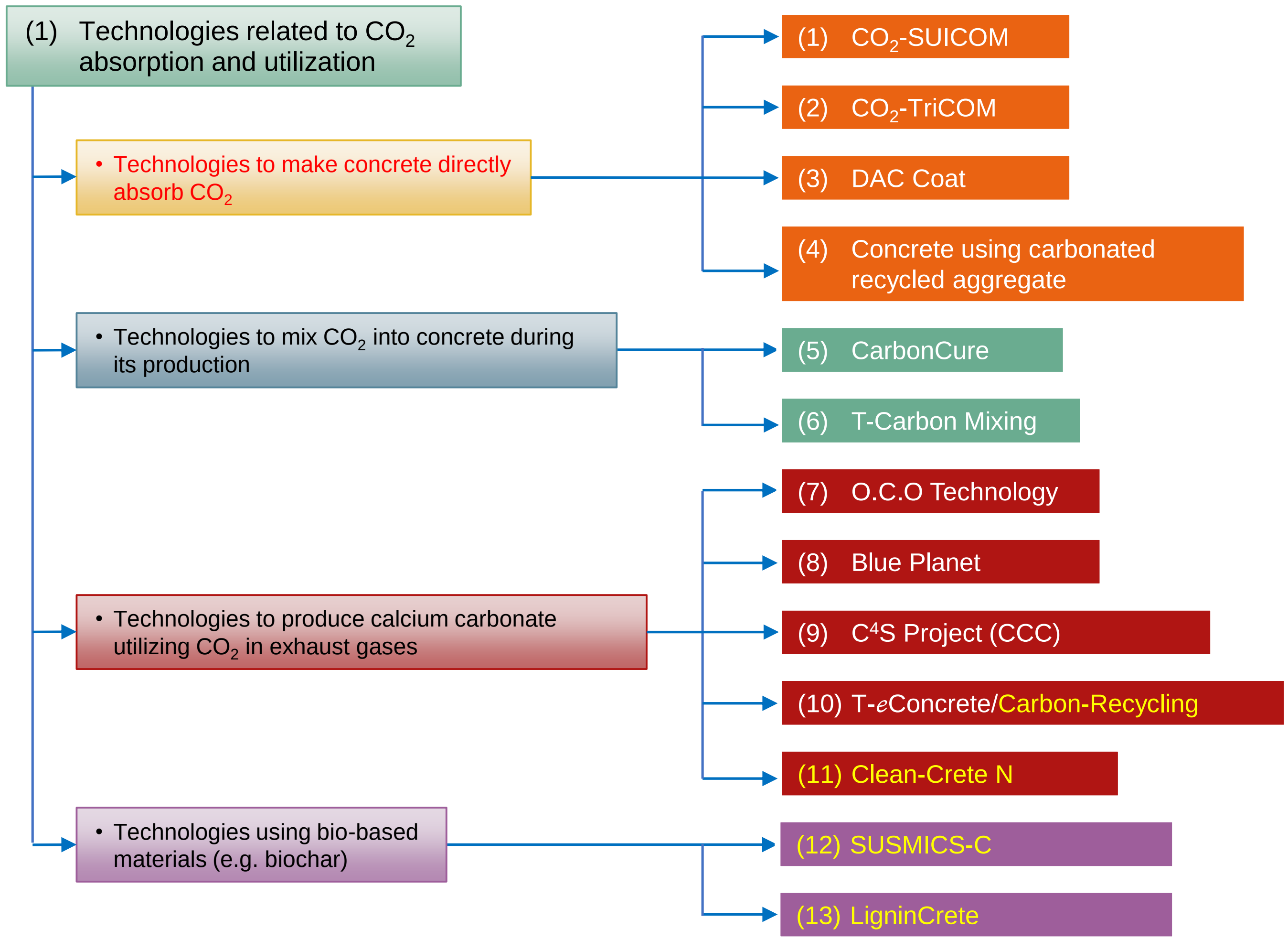

Figure 3.2-1 Technologies for CO_2 absorption and utilization

Trends in CR toward Carbon Neutrality by 2050

- Classification of technologies related to CO_2 emission reduction (Page 38 of the main text)

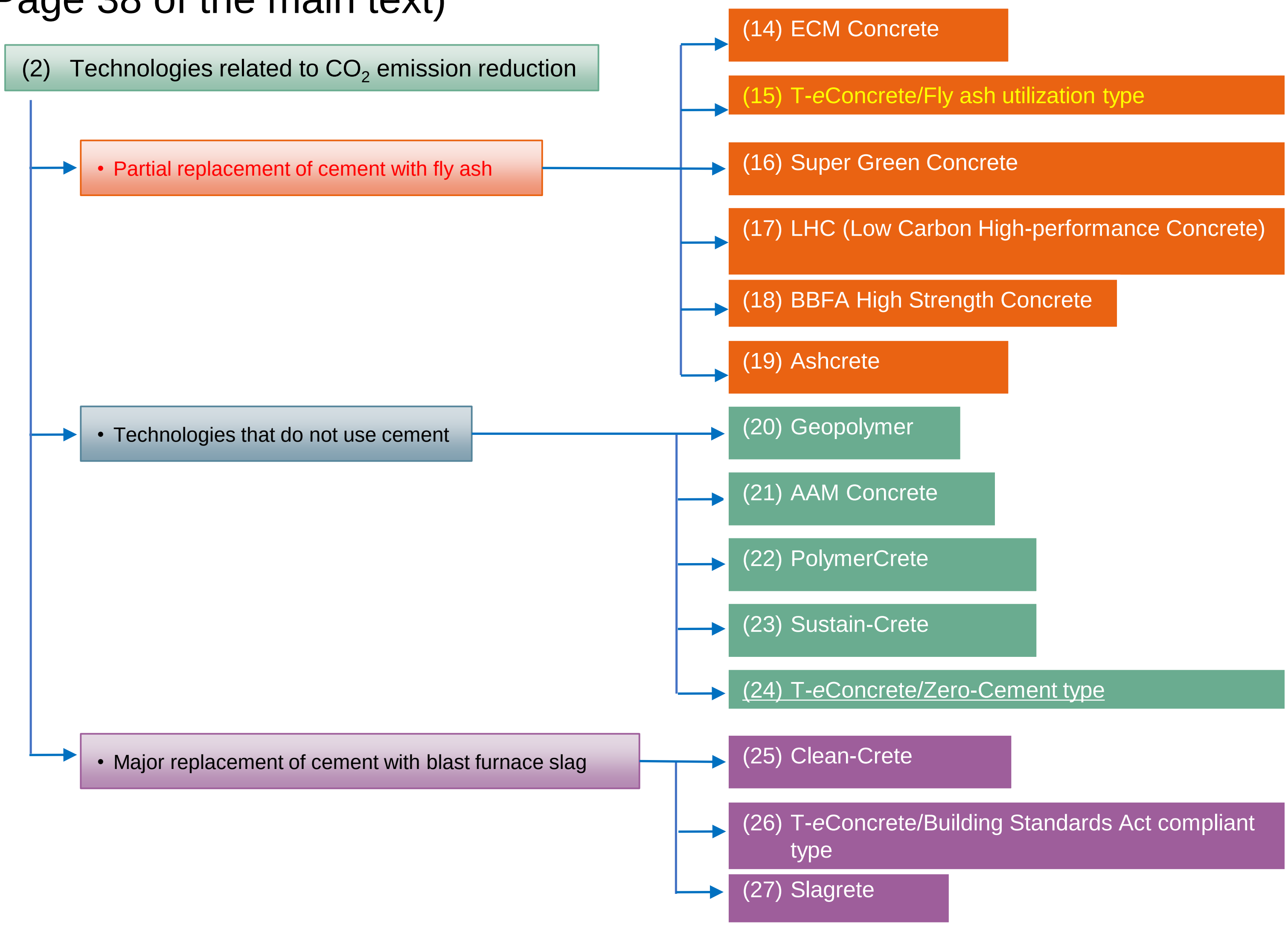

Figure 3.2-2 Technologies for CO_2 emission reduction

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- Example 1 - Technology to make concrete directly absorb CO_2: CO_2-SUICOM (Page 40 of the main text)

(1) CO_2-SUICOM

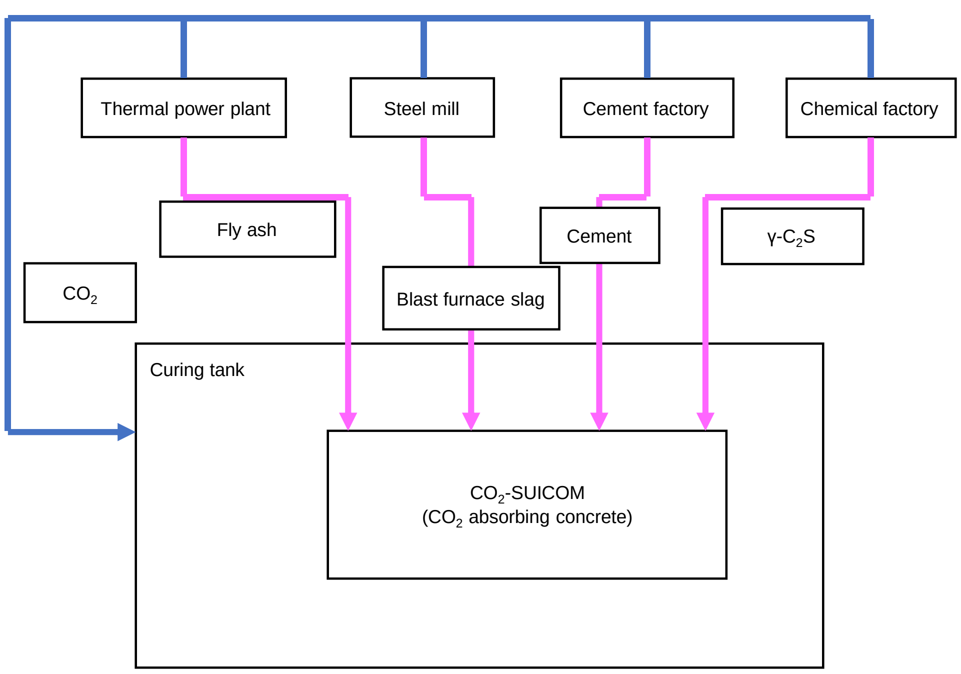
Name of technology	CO_2-SUICOM	Serial number	K-001
Name of company with the technology	Kajima Corporation, the Chugoku Electric Power Co., Inc., and Denka Company Limited		
Conceptual diagram			

Figure 3.2-3 How CO_2-SUICOM works

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- Example 2 - Technology to mix CO_2 into concrete during its production: T-Carbon Mixing (Page 42 of the main text)

(6) T-Carbon Mixing

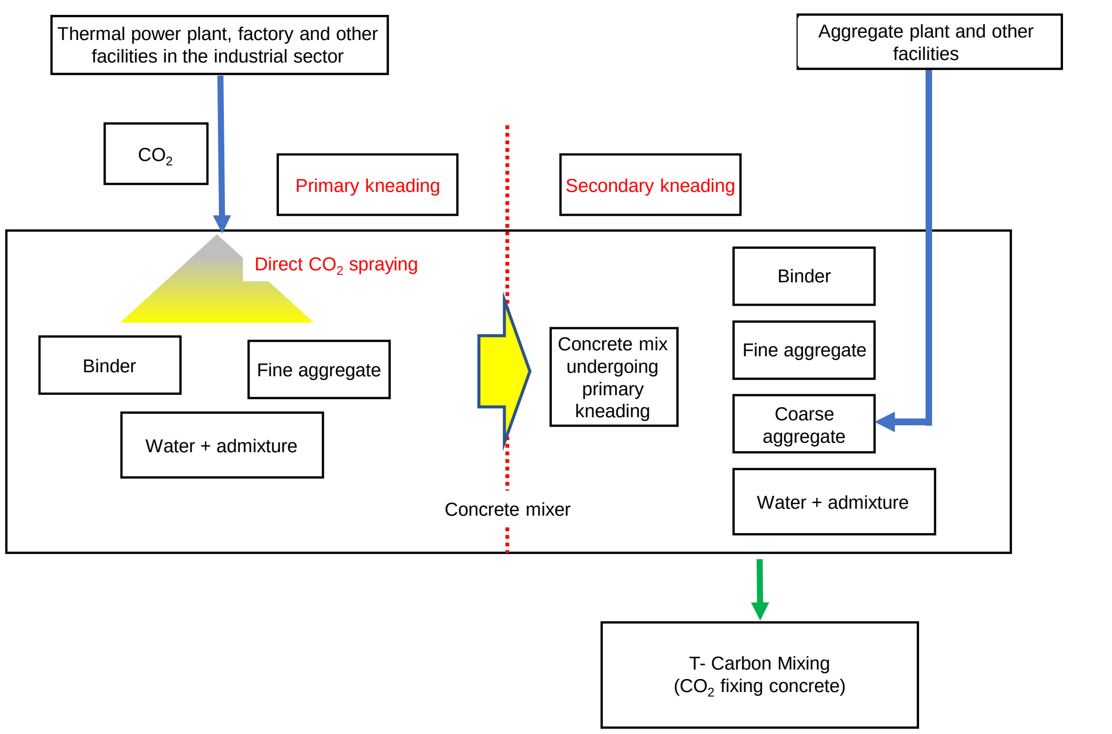
Name of technology	T-Carbon Mixing	Serial number	K-006
Name of company with the technology	Taisei Corporation		
Conceptual diagram			

Figure 3.2-4 How T-Carbon Mixing works

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- Example of technology that incorporates CO_2 as calcium carbonate: O.C.O Technology (Page 43 of the main text)

(7) O.C.O Technology

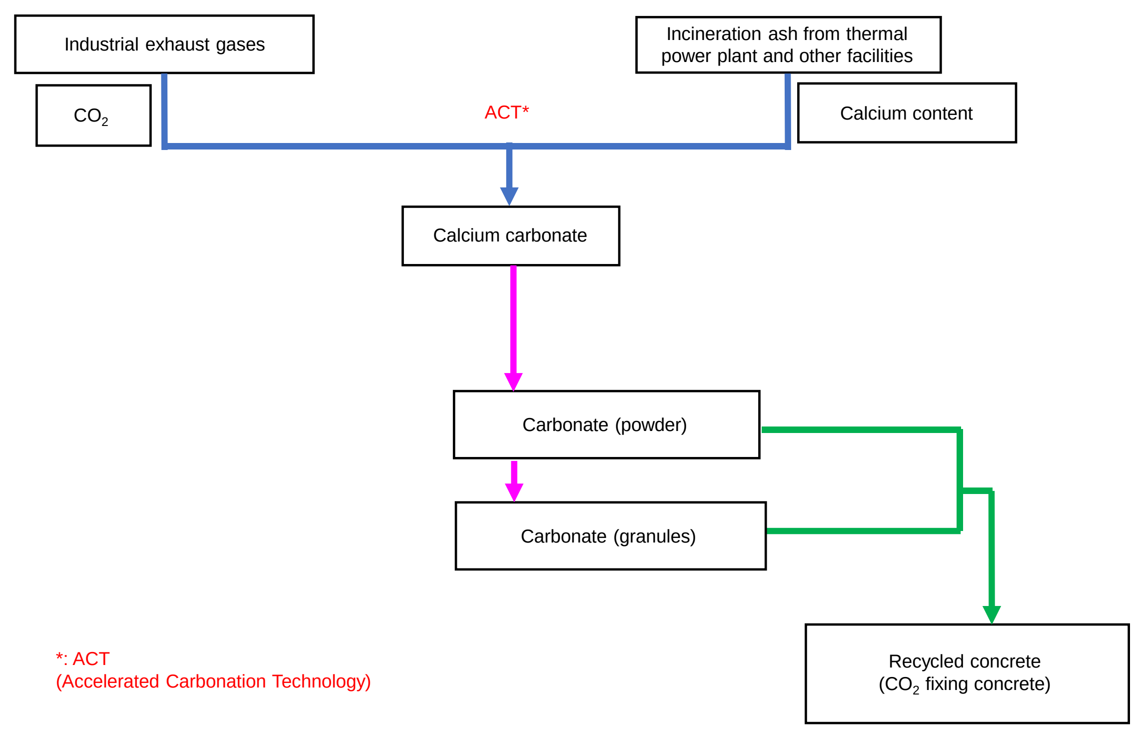
Name of technology	O.C.O Technology	Serial number	K-007
Name of company with the technology	Mitsubishi Corporation		
Conceptual diagram			

Figure 3.2-5 How O.C.O Technology works

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- Example of technology that uses biochar: SUSMICS-C (Page 45 of the main text)

(12) SUSMICS-C

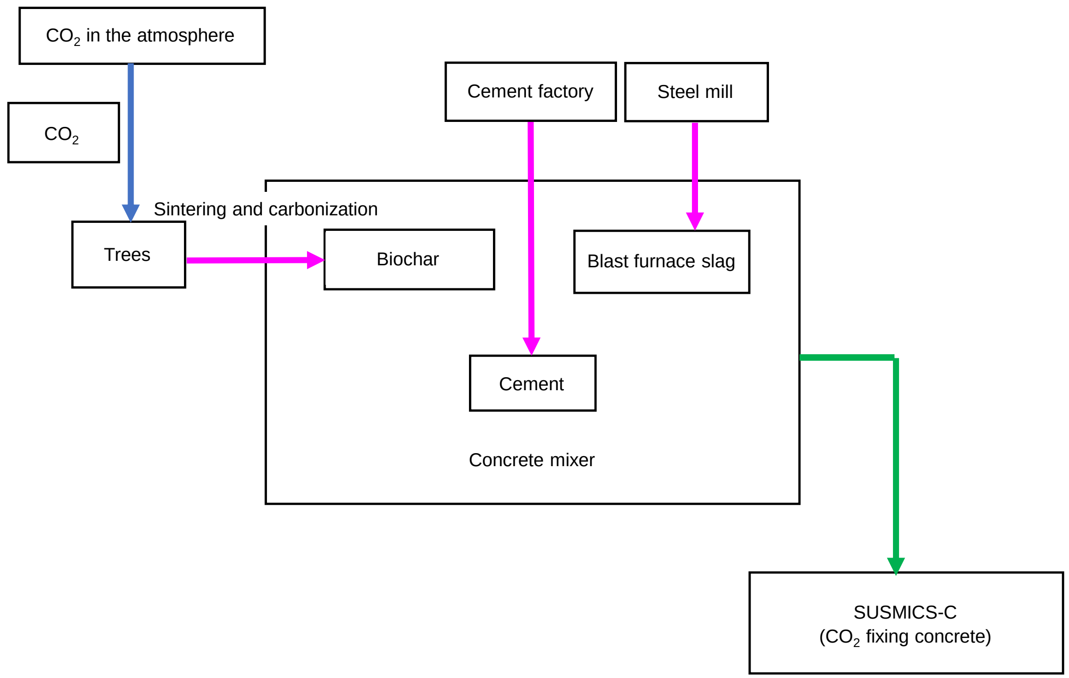
Name of technology	SUSMICS-C	Serial number	K-012
Name of company with the technology	Shimizu Corporation		
Conceptual diagram			

Figure 3.2-6 How SUSMICS-C works

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- Example of technology that partially replaces cement with fly ash: ECM Concrete (Page 47 of the main text)

(1) ECM (Energy, CO_2, Minimum) Concrete

Name of technology	ECM Concrete	Serial number	T-001
Name of company with the technology	Kajima Corporation and Takenaka Corporation		
Compositional summary	(see below)		

Compositional summary:

Constituent materials	Applicability	Remarks
Cement	○	
Fly ash	—	
Blast furnace slag	○	Replacement of 60 to 70% of conventional cement
Silica fume	—	
Other	○	Use of gypsum
CO_2 reduction rate		Approximately 60%

Acquisition of the building material technical performance certificate (GBRC Material Performance Certificate No. 13-11, Revision No. 2 by the General Building Research Corporation of Japan)

Figure 3.2-7 Composition of ECM Concrete

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- Example of technology that does not use cement at all: Geopolymer (Page 50 of the main text)

(7) Geopolymer (Low-carbon concrete)

<table>
<tr><td>Name of technology</td><td>Geopolymer (Low-carbon concrete)</td><td>Serial number</td><td>T-007</td></tr>
<tr><td>Name of company with the technology</td><td colspan="3">National Institute of Technology, Oita College, Yamaguchi University, NIHON KOGYO CO., LTD., and Nishimatsu Construction Co., Ltd.</td></tr>
<tr><td>Compositional summary</td><td colspan="3">
<table>
<tr><th>Constituent materials</th><th>Applicability</th><th>Remarks</th></tr>
<tr><td>Cement</td><td>—</td><td>Not applicable</td></tr>
<tr><td>Fly ash</td><td>○</td><td>As alkali silica powder</td></tr>
<tr><td>Blast furnace slag</td><td>○</td><td>As alkali silica powder</td></tr>
<tr><td>Silica fume</td><td>—</td><td></td></tr>
<tr><td>Other</td><td>○</td><td>An alkali silica solution in which water glass and caustic soda are mixed</td></tr>
<tr><td colspan="2">CO_2 reduction rate</td><td>Approximately 80% (MAX)</td></tr>
</table>
</td></tr>
</table>

Figure 3.2-8 Composition of Geopolymer

- Example of technology that replaces a significant portion of the cement with blast furnace slag: Clean-Crete (Page 52 of the main text)

(12) Clean-Crete

<table>
<tr><td>Name of technology</td><td>Clean-Crete</td><td>Serial number</td><td>T-012</td></tr>
<tr><td>Name of company with the technology</td><td colspan="3">Obayashi Corporation</td></tr>
<tr><td>Compositional summary</td><td colspan="3">
<table>
<tr><th>Constituent materials</th><th>Applicability</th><th>Remarks</th></tr>
<tr><td>Cement</td><td>○</td><td>Partial replacement of conventional cement with blast furnace slag and fly ash</td></tr>
<tr><td>Fly ash</td><td>○</td><td></td></tr>
<tr><td>Blast furnace slag</td><td>○</td><td></td></tr>
<tr><td>Silica fume</td><td>—</td><td></td></tr>
<tr><td>Other</td><td>○</td><td></td></tr>
<tr><td colspan="2">CO_2 reduction rate</td><td>Approximately 80%</td></tr>
</table>
</td></tr>
</table>

Figure 3.2-9 Composition of Clean-Crete

Trends in CR toward Carbon Neutrality by 2050

Table 3.2-3 List of technologies for CO_2 absorption, utilization, and reduction (Page 54 of the main text)

○ Applicable or possibly applicable　　* Under development

Classification	Category	No.	Name of technology	Developing company or organization	Development stage			Application					Type of technology				CO_2 absorption (fixation)					Timing of CO_2 absorption					Cement reduction amount			Admixture used				Other materials used				
					Laboratory test	Test construction	Actual construction	Cast-in-place (plain) concrete	Cast-in-place (reinforced) concrete	Precast product (plain)	Precast product (reinforced)	Other (greening base and embankment materials)	Absorption	Utilization	Reduction	Zero emission or less	Atmosphere	Exhaust gas	Liquid CO_2, etc.	CO_2 cylinder	Other	Before kneading	During kneading	During curing	During service after curing	Other	100%	50% or more	Less than 50%	Blast furnace slag	Fly ash	γ-C_2S	Calcium carbonate	Biochar	Lignin	Amine or amino acid	Alumina silica	Silica fume
Absorption series	Direct absorption	(1)	CO_2-SUICOM	Kajima Corporation, the Chugoku Electric Power Co., Inc., and Denka Company Limited			○	*	*	○	*		○	○	○	○		○		○				○				○		○	○	○						
		(2)	CO_2-TriCOM	The Chugoku Electric Power Co., Inc., Hiroshima University, and Chugoku Koatsu Concrete Industries Co., Ltd.	○							○	○	○	○			○				○							○		○		○					
		(3)	DAC Coat	Shimizu Corporation and Hokkaido University		○		○	○	○	○		○				○	○							○				○						○			
		(4)	Concrete using carbonated recycled aggregate	Tokyo Electric Power Company Holdings, Inc.	○	*		*	*	*	*		○	○				○				○																
	Input during production	(5)	CarbonCure	CarbonCure Technologies, Mitsubishi Corporation			○	○	○	○	○			○	○				○				○						○									
		(6)	T-Carbon Mixing	Taisei Corporation	○			*	*	*	*		○				*	*	*	*			○				○			○	○		○					
	Input of calcium carbonate material	(7)	O.C.O	O.C.O Technology Limited			○	○	○	○	○			○		○		○				○							○				○					
		(8)	Blue Planet	Blue Planet Systems and Mitsubishi Corporation		○		○	○	○	○		○	○		○			○	○		○							○				○					
		(9)	CCC (C^4S Project)	The University of Tokyo and Hokkaido University	○			○	○	○	○			○		○	○						○						○				○					
		(10)	T-*e*Concrete (Carbon-Recycling)	Taisei Corporation			○	○	○					○		○		○					○				○			○	○		○					
		(11)	Clean-Crete N	Obayashi Corporation			○	○	○	○	○			○	○	○		○					○					○		○	○		○					
	Input of biochar	(12)	SUSMICS-C	Shimizu Corporation			○	○	○	○	○			○		○	○ ?				○ ?		○						○	○				○				
		(13)	LigninCrete	Obayashi Corporation, Nippon Paper Industries Co., Ltd., and Flowric Co., Ltd.		○		○		○				○			○				○		○												○			
Reduction series	Partial replacement with fly ash	(14)	ECM Concrete	Kajima Corporation and Takenaka Corporation			○	○	○						○													○		○	○							
		(15)	T-*e*Concrete (fly ash utilization type)	Taisei Corporation			○	○	○						○														○	○	○							
		(16)	Super Green Concrete	Maeda Corporation			○	○	○						○													○		○	○							
		(17)	LHC (Low Carbon High-performance Concrete)	Hazama Ando Corporation			○	○	○	○	○				○														○	○	○							
		(18)	BBFA High Strength Concrete	Hazama Ando Corporation			○	○	○	○	○				○														○	○	○							
		(19)	Ashcrete	Hazama Ando Corporation			○	○		○					○														○	○	○			○				
	No cement use	(20)	Geopolymer	Nishimatsu Construction Co., Ltd., National Institute of Technology, Oita College, and Nihon Kogyo Co., Ltd.		○				○					○												○			○	○					○		
		(21)	AAM Concrete	Nishimatsu Construction Co., Ltd., JFE Steel Corporation, Tohoku University, and Nihon University			○	○	○	○	○				○												○			○								
		(22)	Cast-in-place Geopolymer (PolymerCrete)	Obayashi Corporation and Pozzolith Solutions Ltd.			○	○	○						○												○			○	○							○
		(23)	Sustain-Crete	Sumitomo Mitsui Construction Co., Ltd.	○	○	○	○	○	○	○				○													○	○	○	○						○	
		(24)	T-*e*Concrete (Zero-Cement type)	Taisei Corporation			○	○	○	○	○				○												○			○			○					
	Significant replacement with blast furnace slag	(25)	Clean-Crete	Obayashi Corporation			○	○	○	○	○				○													○		○	○							○
		(26)	T-*e*Concrete (Building Standards Act compliant type)	Taisei Corporation			○	○	○						○													○		○								
		(27)	Slagrete	Toda Corporation and Nishimatsu Construction Co., Ltd.			○	○	○						○													○		○								