A serene sunset scene in a forest. The sun is a bright orange orb positioned in the upper center, partially obscured by the dark, vertical trunks of trees. The light from the sun filters through the canopy, creating a warm, golden glow. In the foreground, a field of small, vibrant purple flowers is in focus, adding a touch of color to the scene.

DAC R&D Status and Roadmap of GS E&C

Dec. 01, 2023

Carbon Solution Research Team / GS E&C

Kitae Kim

Introduction - GS Group

GS Group is the one of largest asset-holding company in Korea and total asset is 61 billion USD and sales is 44 Billion USD

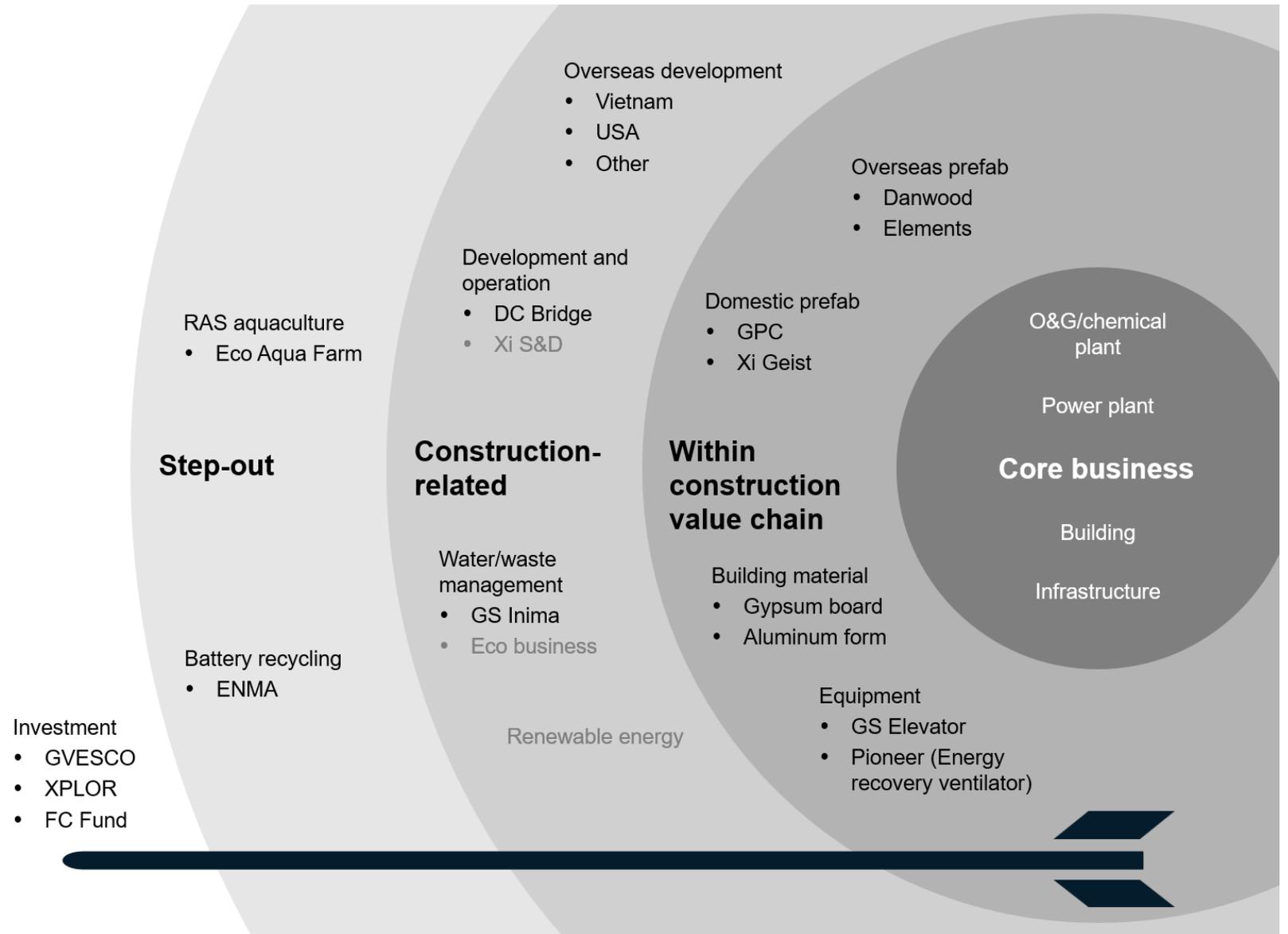


<p>61 Billion Total Assets (USD)</p>	<p>44 Billion Sales (USD)</p>	<p>36,000 Employees</p>	<p>32 Countries</p>	<p>67 Subsidiaries</p>
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The inception of GS E&C took place in 1969, when it became the construction powerhouse within GS Group.

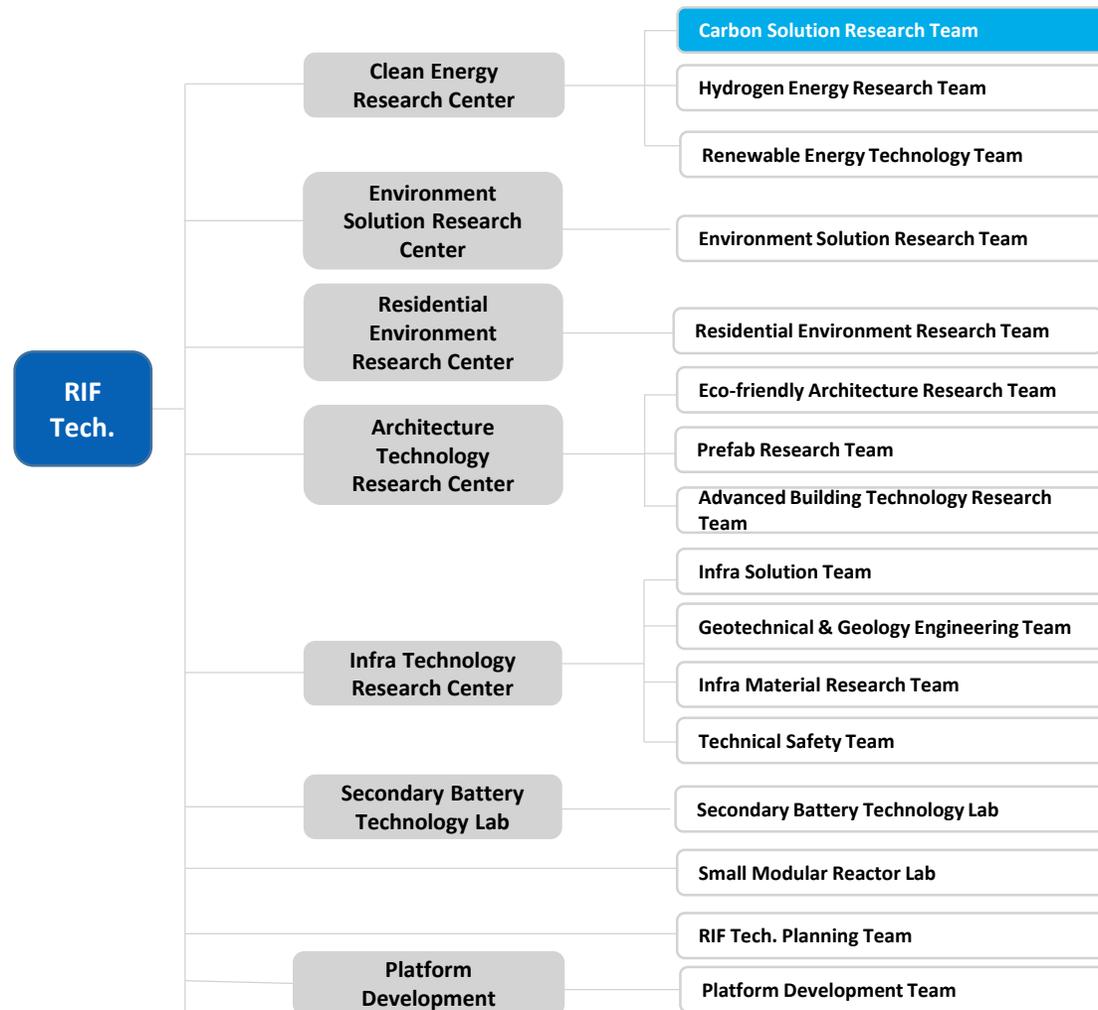
GS E&C's expertise isn't confined to conventional construction domains. While its proficiency spans engineering and construction of plants, infrastructure, and buildings, the company's influence reaches far beyond the realm of typical contractors. GS E&C has ventured into a diverse range of new businesses, all intricately connected to its core endeavors.

Moreover, setting itself apart from the norm within the construction industry, GS E&C spearheads an autonomous research institution dedicated to pioneering future technologies. The purview of this institution encompasses a wide array of subjects, extending beyond the confines of conventional construction. These include, but are by no means restricted to, methodologies for **decarbonization**, exploratory studies on **Small Modular Reactors (SMRs)**, innovations in **smart home technologies**, advancements in construction technologies including **modular, and digital transformation.**



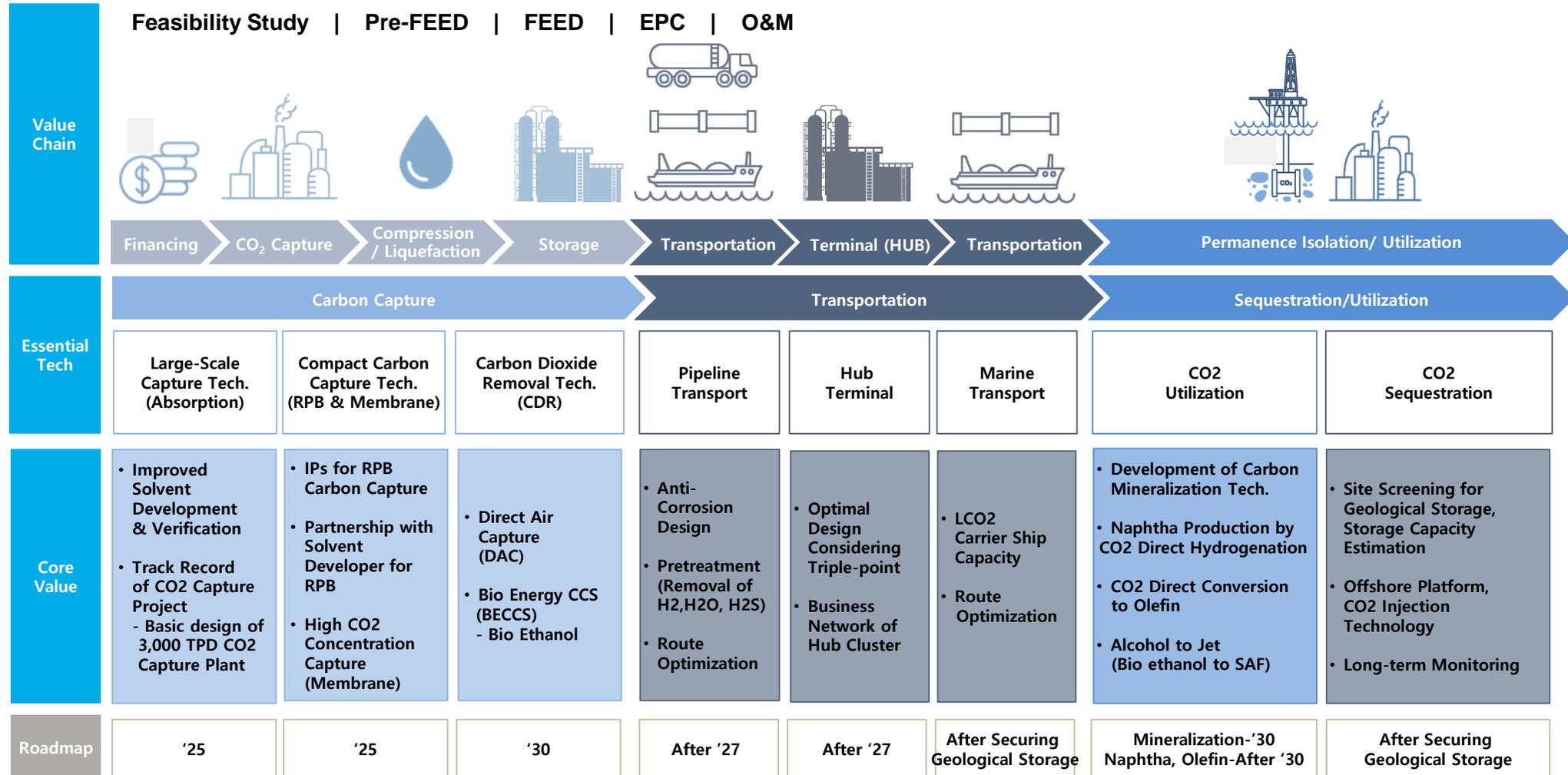
Introduction - RIF Tech.

GS E&C is making a full preparation for securing global core capabilities along with strategic nurturing of the new growth business. Therefore, GS E&C expands R&D organization (RIF Tech., Research Institute for Future Technology) which will intensively proceed R&D and develop related business.



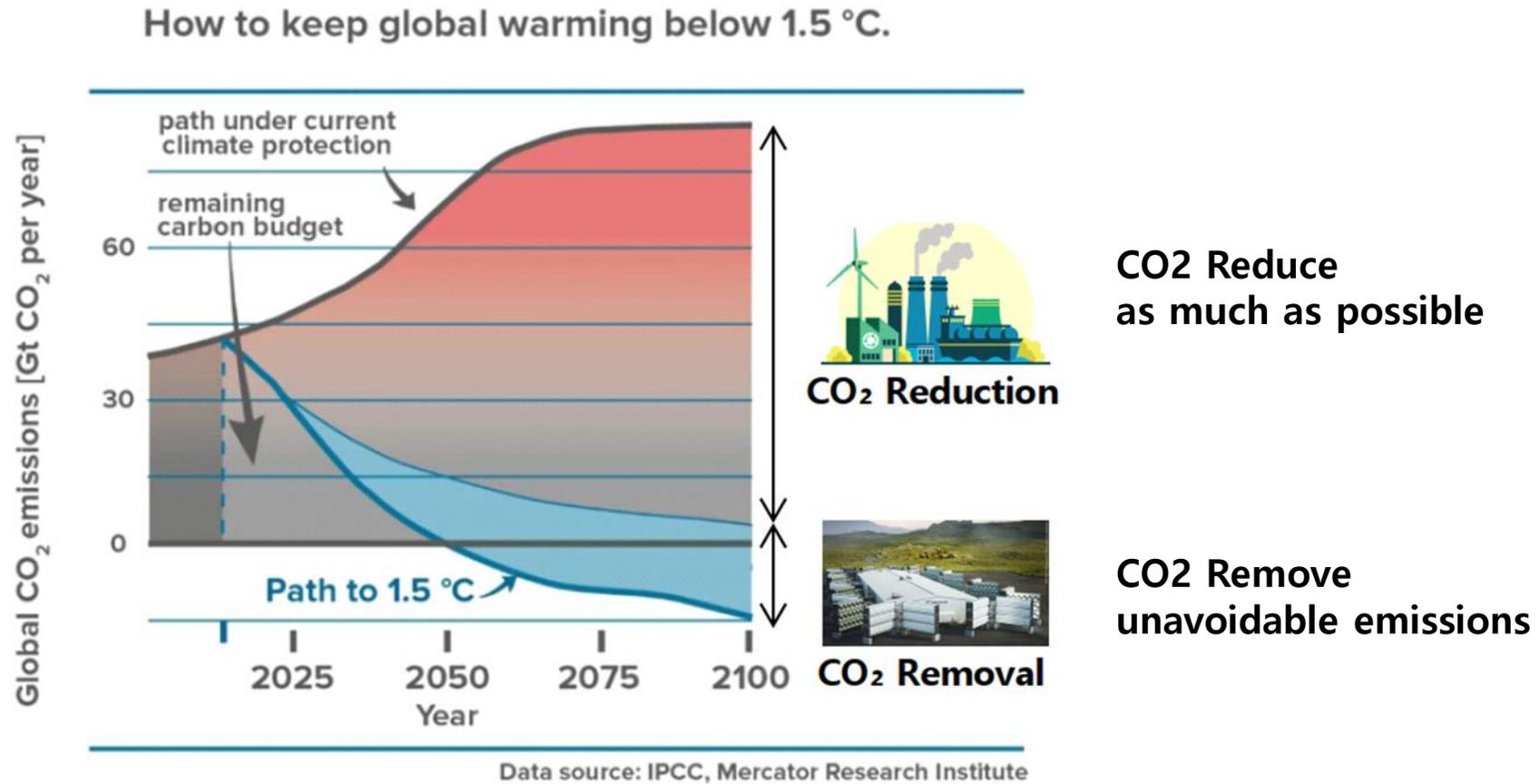
Introduction - Carbon Solution Research Team

In order to secure capabilities as a CCUS Total Solution Provider, Carbon Solution Research Team is making a full preparation for large-scale / compact / customized carbon capture technology and securing CCUS-related core technology and business network through our own and government projects.



Why DAC ? - (1) Carbon dioxide removal (CDR) is crucial requirement

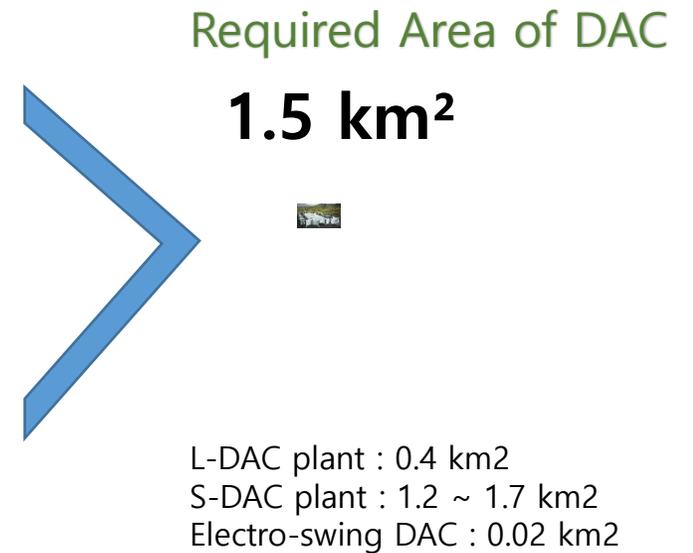
To keep global warming below 1.5°C, we should reduce Global CO₂ emissions to Zero by 2050. However, there will still be around 15 Gt CO₂ of unavoidable emissions remaining. Carbon Dioxide removal (CDR) is a crucial technology to neutralize these emissions.



Schematic illustration of NET deployment timing and scale².

Why DAC ? - (2) Smaller area is enough than afforestation

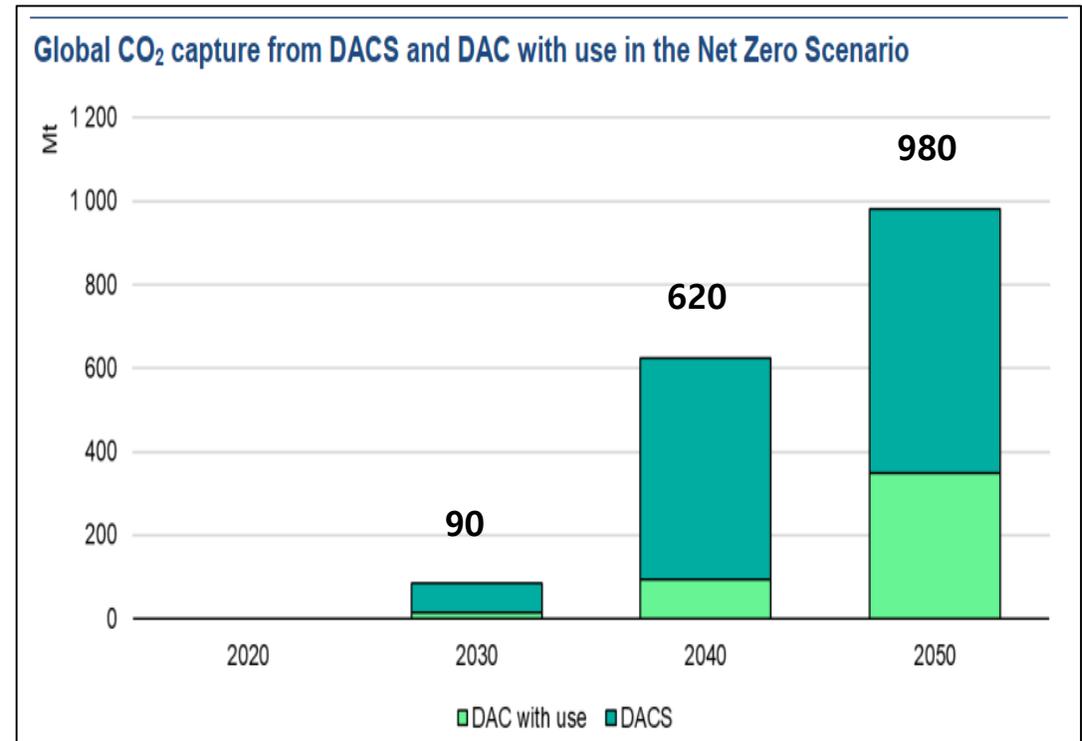
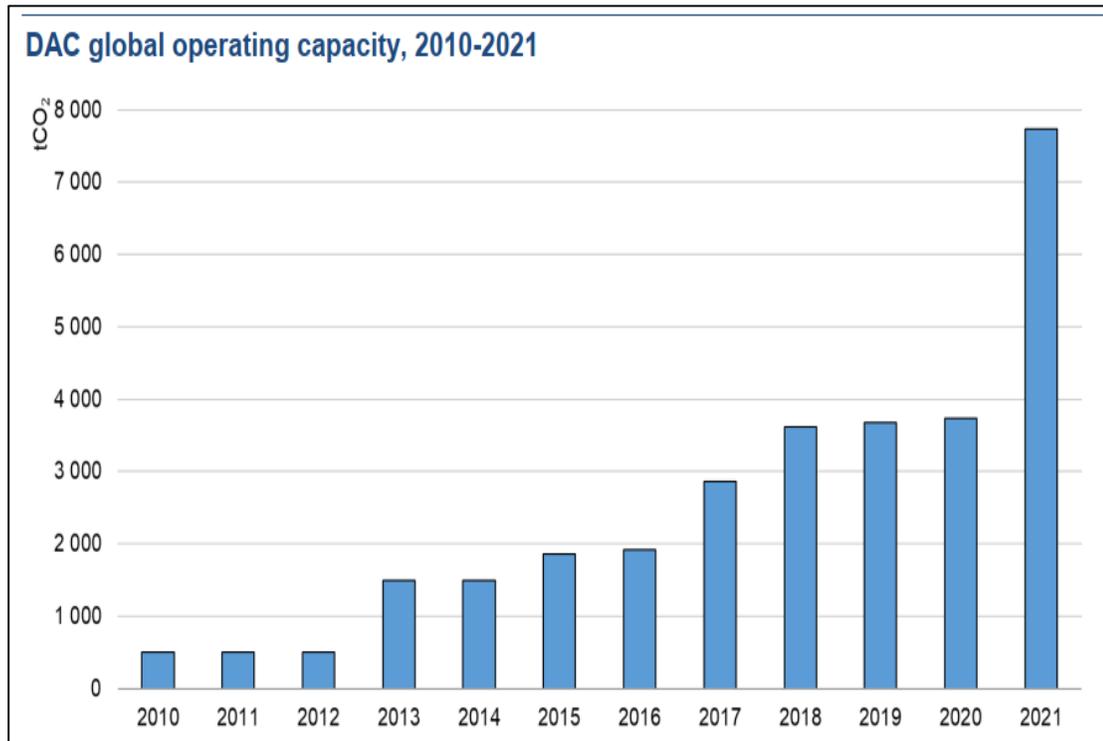
The area needed to remove 1 million tons of CO₂ is 800 km² when creating a forest, and 1.5 km² when capturing it through direct air capture (DAC). A difference is about 530 times.



Why DAC ? - (3) Huge market will be come soon

18 DAC plants, total capacity of 7,700 tCO₂/year are currently operational globally and are located in Canada, Europe and the US. In 2030 almost 90 MtCO₂/year is captured via DAC, accelerating significantly to reach 620 MtCO₂/year in 2040 and 980 MtCO₂/year in 2050.

If carbon price is about 100 dollars, the market size is 'One hundred Billion USD' in terms of carbon price in 2050.



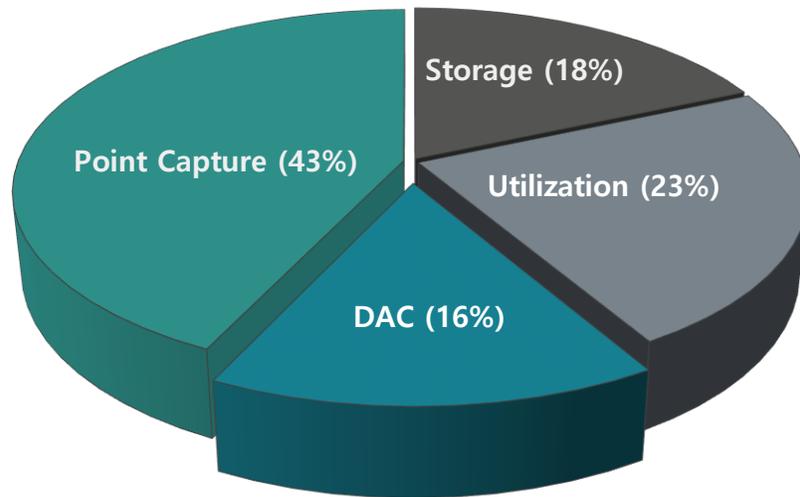
IEA, Direct Air Capture_2022

Why DAC ? - (4) Government support is growing

Looking at the United States, many R&D projects have already been started in progress. NETL, the CCUS research support organization of US government shows that there are 214 CCUS projects of which 33(16%) are DAC projects in 2023.

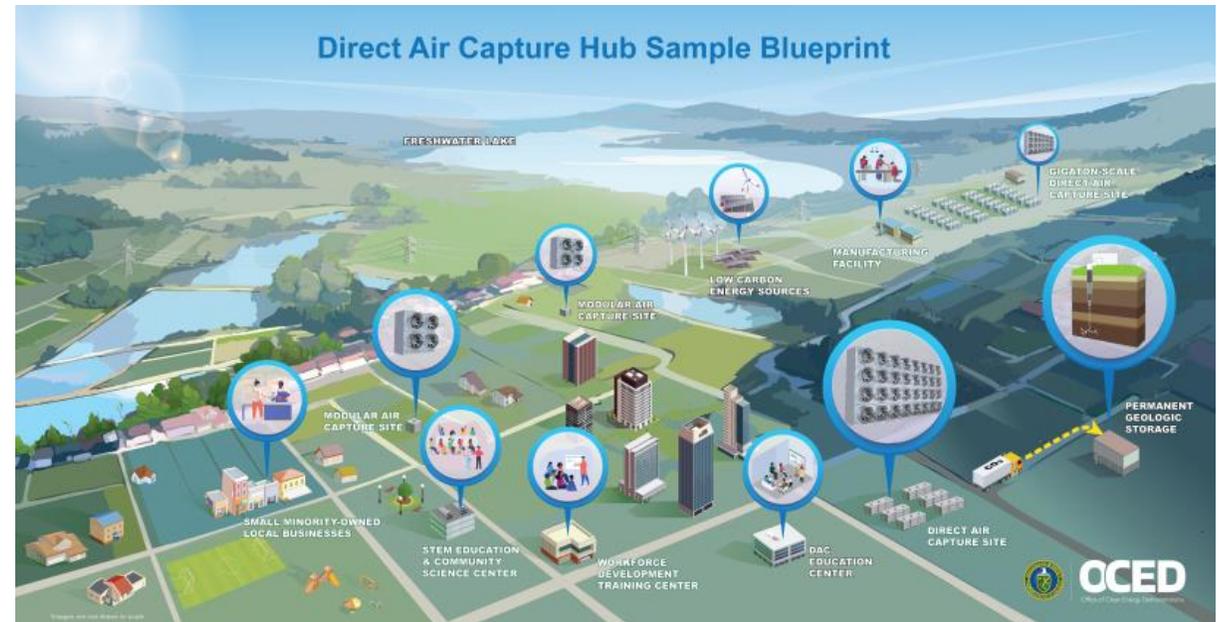
The Regional DAC Hubs Program received a combined \$3.5 billion to help accelerate the demonstration and deployment of direct air capture technologies.

NETL CCUS R&D Status, May 2023



■ storage ■ utilization ■ DAC ■ Point Capture

* Data from NETL, National Energy Technology Laboratory homepage



DOE awards \$1.2 billion in Aug 2023

- 1) Cypress in Louisiana - Battelle, Climeworks, and Heirloom Carbon Technologies;
- 2) South Texas DAC Hub in Texas - 1PointFive and partners Carbon Engineering Ltd and Worley.

Why DAC ? - (5) Private support and investment is taking off

Private-sector support for and investment in DAC has expanded in recent years, with organisations such as Breakthrough Energy Ventures in early-stage start-ups as well as more established companies that are already capturing CO2 from the atmosphere. These private investments can assist in the development of large-scale operations, de-risking newer or emerging technologies, and propelling DAC forward in the absence of other incentives for carbon removal and storage.

\$100M PRIZE FOR CARBON REMOVAL

PHASE | Active

XPRIZE CARBON REMOVAL | MUSK FOUNDATION

OUR WORK

Breakthrough Energy Catalyst

Accelerating the Deployment of Emerging Climate Technologies

climeworks Act now

Breaking the record for the largest ever investment into direct air capture: Investment into Climeworks boosted to CHF 100 Million (USD 110M)

Frontier

Dollars contracted: **\$112.5M** (➤ \$1071M since fall 2022)

Tons contracted: **203,491** (➤ 194K since fall 2022)

Project locations

Members
Members make large, multi-year purchase commitments directly with Frontier

Projects by pathway
We're building a diverse portfolio to maximize the likelihood of meeting our global climate goals.

Pathway	Count
Direct air capture	10
Enhanced weathering	8
Biomass carbon removal & storage	7
Direct ocean removal	3
Ocean alkalinity enhancement	2
Storage only	2

Member logos: stripe, Alphabet, shopify, Meta, McKinsey Sustainability, AUTODESK, H&M Group, JPMORGAN CHASE & CO., workday.

Frontier Carbon Removal Fund Makes New \$46.6 Million Direct Air Capture Purchase

16 Nov, 2023

- Frontier carbon removal fund buys services from two startups
- Market for carbon removal can grow to nearly \$1 trillion

Why DAC ? - (5) Private support and investment is taking off



- Carbon Removal – 11 members**
- AES
 - Alphabet
 - Boston Consulting Group
 - Capgemini
 - Drax
 - EGA
 - Microsoft
 - Mitsui O.S.K. Lines
 - Salesforce
 - SwissRe
 - Trafigura

“In addition to our maximal direct emissions reduction efforts, we commit to contract for **at least 50,000 tons** of durable and scalable (per FMC definitions) net carbon removal to be achieved **by the end of 2030.**”

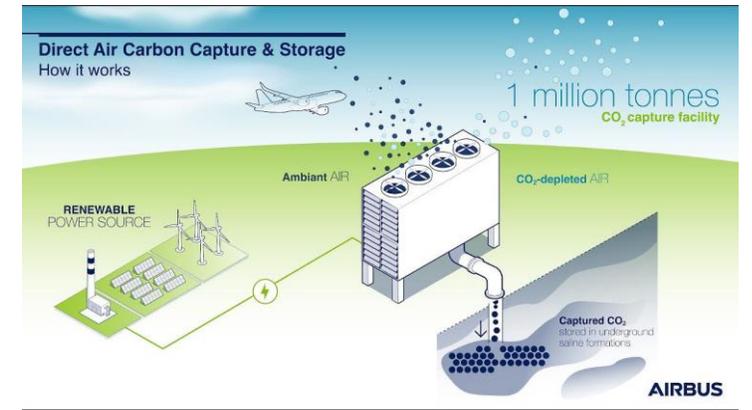
NextGen



OUR AMBITION:
To purchase +1 million certified, long term carbon removals by 2025



Shopify has purchased more Direct Air Capture (DAC) carbon removal than any other company in history. This milestone comes with our agreement to purchase 10,000 tonnes of removal from Carbon Engineering, adding to a previous 5,000-tonne commitment to Climeworks. (March 9, 2021)



ANA Announces Carbon Dioxide Removal Purchase from 1PointFive

ANA has agreed to purchase 10,000 metric tonnes of CDR credits per year for three years beginning in 2025. (Aug. 1, 2023)



Amazon is supporting the world's largest deployment of DAC technology by committing to purchase 250,000 metric tons of carbon removal over 10 years from STRATOS, 1PointFive's first DAC plant.

DAC R&D Road Map of GS E&C

In order to enter by 2030 in the DAC market, GS E&C is developing not only basic technology research but also system research for commercialization. To this end, we are currently researching basic technology on DAC sorbents and systems with the Korea Institute of Energy Research, KAIST, and Korea University as part of a project by the Ministry of Science and ICT. In addition, we are working the Alchemist Project, as part of a project of the Ministry of Trade, Industry and Energy, to find models that can be used in cities.

Based on these research results, we plan to make business models and develop competitive DAC modules.

In particular, in the advanced sorbent sector, we plan to enter the market more quickly through cooperation with not only domestic researchers but also overseas companies.

We have plan to secure performance and expand our business overseas by constructing and operating 100 tons/year DAC demonstration facilities by 2029.

	Short-term			Mid-term			Long-term	
	'23	'24	'25	'26	'27	'28	'29 ~	
Phase 1 (R&D for Material)	R&D for Sorbent and Contactor system <ul style="list-style-type: none"> • MSIT DAC R&D project with KIER, KAIST, Korea Univ. • MOTIE Alchemist Project for DAC in City with KIER, KAIST, Korea Univ. 			C & D for Advanced Sorbent <ul style="list-style-type: none"> • Amine, Zeolite, MOF and others 				
Phase 2 (Lab / Pilot Test)		Lab Test <ul style="list-style-type: none"> • 1 kg CO2/day Capturing test • 10 kg CO2/day Capturing test 			Pilot Test <ul style="list-style-type: none"> • 50 kg ~ 100 kg CO2/day Capturing test 			
Phase 3 (Demo Plant)					Demo Plant Construction & Operation <ul style="list-style-type: none"> • 100 tCO2/year Capturing Plant 			
Commercial						Entering the Market <ul style="list-style-type: none"> • Modular for City Building • Modularization • EPC contract 		

Project Leader :  한국에너지기술연구원
KOREA INSTITUTE OF ENERGY RESEARCH

- Project Period : 2023. 4 ~ 2025.12
- Total Budget : 8,380 Mil. KRW (about 6.5 Mil USD)

DAC Sorbent

- Amine, Alkali material
- Zeolite
- MOF (Metal Organic Frameworks)
- Mass Production

 한국에너지기술연구원
KOREA INSTITUTE OF ENERGY RESEARCH



 고려대학교
KOREA UNIVERSITY

Development of advanced solid sorbent and 10 kg/day-scale low differential pressure continuous fixed-bed system for direct air capture

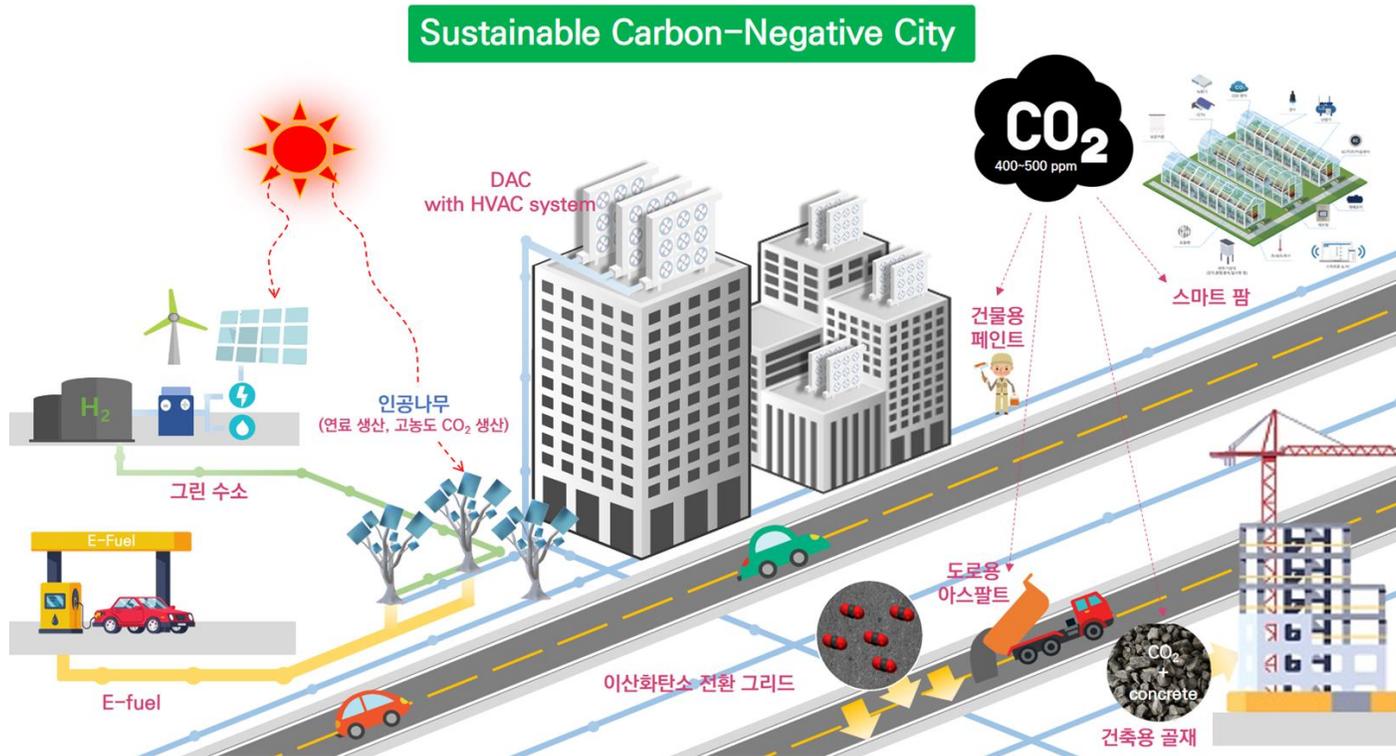
Low DP DAC System

- Integrated system analysis
- CFD for DAC system
- Optimization of DAC system design

 한국에너지기술연구원
KOREA INSTITUTE OF ENERGY RESEARCH



 Ministry of Science and ICT



Project Leader : KIER 한국에너지기술연구원
KOREA INSTITUTE OF ENERGY RESEARCH

2023 : 1st stage competition
2024 : 2nd stage competition
2025~2029 : 3rd stage

- Project Period : 2023. 4 ~ 2029.12
- Total Budget : 20,831 Mil. KRW (about 16 Mil USD)

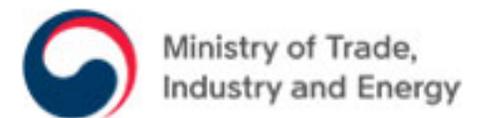


(Building CCS) Links HVAC systems and DAC technology in city buildings for greenhouse gas reduction technology

(Road CCS) Development of high-concentration CO₂ recovery technology based on road facility DAC (Artificial trees, etc.)

(Energy Infrastructure CCUS) Development of CO₂ utilization product production technology through application of RCC (Reactive Capture & Conversion) technology utilizing roads and building facilities

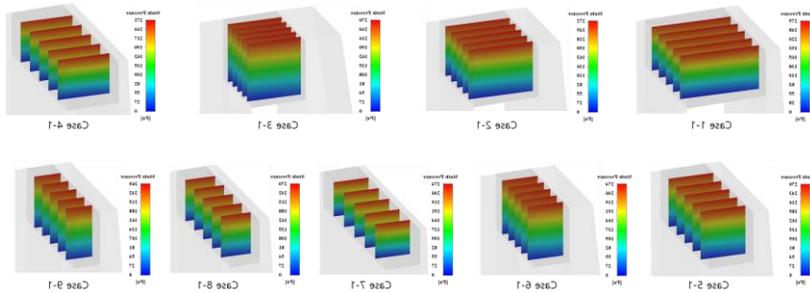
(CO₂ sequestration) Development of a product that sequester carbon dioxide in the atmosphere (building exterior materials, asphalt replacement materials, artificial road paving materials, etc.)



1. Design parameters through CFD and Process Simulation Study

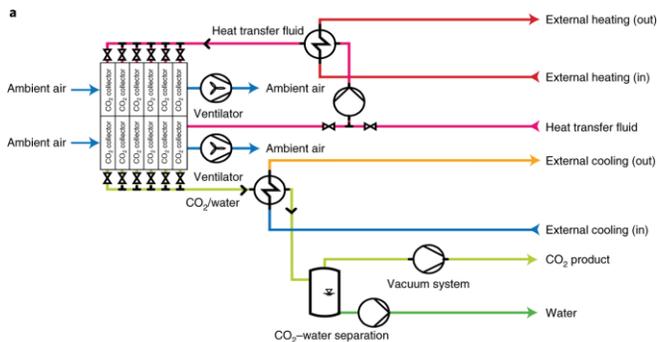
• CFD Study

- Optimization of module internal design using CFD
- Comparison of flow distribution characteristics by design variable
- Reflection of design according to results



• Process Simulation Study

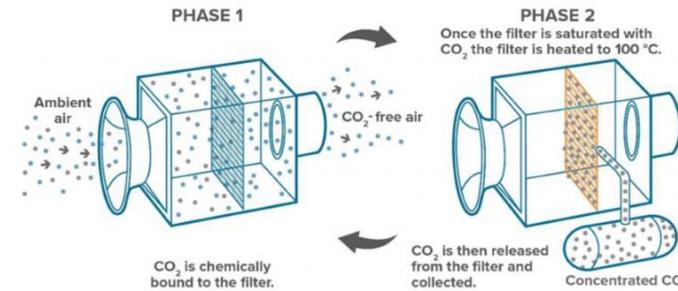
- System analysis through laboratory operation data
- Basic design through process simulation
- Process Optimization : Productivity, Energy



2. System development & Test

• Module system design with equipment vendor

- Securing efficiency/performance factors through partners
- System optimization plan through data analysis
- Cost effective design



Schematic illustration of Climeworks direct air capture process

3. Monitoring trends & Making relationship for cooperation

• Making relationship with Global DAC companies

- Direct Air Capture Coalition
- NETL Carbon Dioxide Conversion Program – DAC Center
- Climeworks, Carbon Engineering, Global Thermostat, Heirloom, Capture 6, Air Capture, etc.

Thank
you

