



Catalyzing a Net-Zero Semiconductor Value Chain

SEMICON SEA Sustainability Forum

Post Forum Report

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Forward



"The semiconductor industry faces unique, sector-specific challenges on the path to net-zero, driven by the high global warming potential process gases and poor access to clean energy in regions of operation. While the industry continues to innovate aggressively and prioritizes deep emissions reductions today, in operations, we recognize that residual carbon removal must also be part of the equation eventually. Due to complexity of the innovation required for direct and indirect emissions reduction AND the limited availability of high-quality credits coupled with the long lead time involved in their installation, these two efforts cannot happen sequentially. SEMI recognizes the need to start setting up greater awareness, education, and development of tailored standards and guidelines providing an on-ramp for our members into the carbon removal space. We plan to build the resources to equip our members in partnership with organizations like Emerald Climate."

Dr. Mousumi Bhat, Vice President for Sustainability, SEMI

Purpose

This report summarizes key content and takeaways from the SEMICON Sustainability Forum session on "Catalyzing a Net-Zero Semiconductor Value Chain" and offers recommendations for the industry for achieving net-zero goals.

Audience

Semiconductor industry, policymakers, the financial community, technology and nature-based solutions providers, and other key stakeholders aiming to support the decarbonization of the semiconductor industry.

Vision

A thriving semiconductor industry that leads global decarbonization efforts grounded in collaboration, transparency, and ambition, while maintaining economic competitiveness.

About the event

SEMICON Sustainability Forum: Catalyzing a Net-Zero Semiconductor Value Chain

Co-hosted by SEMI and Emerald Climate, this half-day summit brought together global semiconductor leaders, investors, policymakers, and climate innovators to chart actionable net-zero strategies through scalable nature-based strategies.

With rising chip demand and intensifying emissions targets, the focus was on scaling high-integrity carbon removal, both nature-based and tech-driven. Attendees assessed market readiness and regional deployment pathways for carbon dioxide removal (CDR), spotlighting the semiconductor sector's unique ability to shape demand signals, take an active role in infrastructure design, and pilot credible standards for the industry's transition.



Key themes covered

Rather than showcase technologies, this Forum, a first at SEMICON, was designed as a focused, dialogue, bringing semiconductor sustainability leaders, climate innovators, industry executives, and policymakers together to evaluate real barriers to scaling critical carbon removal solutions.

Discussions covered incentives, risks, and infrastructure gaps shaping carbon removal adoption, highlighting the role SEMI member companies can play in anchoring credible demand, piloting standards, and accelerating pathways to net-zero.

Highlights included

Roundtables featuring leaders in innovation from a range of nature-based and tech-based solutions providers.

A fireside chat with the CEO of Keppel Infrastructure on Singapore's pursuit of carbon management and Keppel's role as an innovation engine.

A frank discussion between first-movers who have paved the way in shaping carbon removal procurement best practices and semiconductor companies who are starting to explore how carbon removal fits into their respective net-zero strategies.



The Film: *Legion 44* Watch + Remove CO₂



A powerful film showcasing humans building cutting-edge technology companies to tackle our greatest crisis

Visionary Direction

Directed by acclaimed filmmaker **Leila Conners**, known for her environmental storytelling and powerful visual style.

Compelling Narration

Narrated by **Walton Goggins** (Django Unchained, White Lotus), bringing depth and urgency to the film's message.

Captivating Soundtrack

Original score by **Marc Streitenfeld**, longtime Ridley Scott collaborator, enhancing the film's emotional impact.

Innovative Solutions

Legion 44 marries cinematic storytelling with urgent environmental action, featuring innovations from **Climeworks** DACCS (Switzerland), **Octavia Carbon** DACCS (Kenya), **Carbonfuture** Biochar, (East Africa), **Planetary** OAE (Canada), **44.01** Mineralization (Oman), **Heirloom** DACCS (USA).

SEMICON SEA 2025 speakers received exclusive access to *Legion 44*, while removing 80kg of CO₂ in their name.

The big picture

High-integrity carbon removal credits and well-functioning carbon markets are key to unlocking regional deployment, and Singapore is uniquely positioned to steer a regional transformation.

With its financial strength, strategic location, innovation ecosystem, and Article 6 leadership, Singapore is already advancing regional grid connectivity, launching climate finance platforms like FAST-P, and shaping global carbon markets standards. In a region that will feel the full brunt of climate change, Singapore is not just a realist, it's a catalyst.

As demand for chips, and the data centers they power, emissions across the semiconductor industry are expected to rise. The industry has a unique opportunity to lead by creating demand for high-integrity carbon removal credits, helping tackle residual emissions and keeping net-zero targets within reach.

Industry context

The billion-dollar opportunity: semiconductors x carbon removal  **\$2.5-10B**

- \$2T invested in global energy transition in 2024, \$600B in Electric Vehicles (EV) alone
- EV boom drove 7-10% of chip revenue growth, potentially a roadmap for CDR
- Over \$4 billion has already been invested in engineered carbon removal solutions, with the market for tech-based CDR projected to reach up to \$100 billion annually by 2030.
- Direct Air Carbon Capture and Storage (DACCS), bio-oil, mineralization, etc., represent infrastructure markets that need chips (sensors, power management, control)
- Semiconductors are key to enabling sensors, controls, and thermal management in carbon removal tech. drive \$2.5-10 billion in annual demand for carbon removal infrastructure.

Acknowledgment: Harris Cohn, Charm Industrial

\$2T Energy
Transition
\$600B EV

The regional case: Singapore's role in climate-aligned chip innovation

- CDR systems need chips for harsh environments, thermal control, real-time sensing, and edge computing
- New chip research and development (R&D) is critical for power optimization, secure Measurement, Monitoring, Reporting, and Verification (MMRV), and integrated system performance
- Singapore's planned national semiconductor R&D hub can lead in climate-aligned chip innovation, positioning Singapore as a global hub for engineered climate solutions + advanced electronics
- Align R&D with emerging carbon removal infrastructure needs and global net-zero goals

What we heard



Fast followers

Critical interdependency between SEMI companies and hyperscalers, reinforcing a shared responsibility across complex value chains. Development and adoption of credible norms and standards for F-gas substitution and complementary CDR are especially urgent.



Revenue opportunities

CDR could follow the same trajectory as EVs, creating revenue for SEMI companies and offering opportunities for Singapore. CDR emerging alongside opportunities in green hydrogen, carbon-negative iron, sustainable building materials and lower carbon fuels.



Standards, a role for industry

MMRV, cross-border storage, credit integrity, these rules are still being written. The chip industry can contribute to shaping them.



Cross-border initiatives

CCS negotiations provide a framework for CDR. Singapore is positioned to lead regional efforts.



Keppel leading across the entire carbon management ecosystem

Keppel transitioning from power supplier to decarbonization partner, offering 10+ year bundled services, like low-carbon power, cooling, and infrastructure. Cross-border carbon management initiatives require careful framing, public-private partnerships, and community engagement.

A portfolio of carbon removal solutions to restore land, boost yields, remove waste, lock away emissions and support economic growth

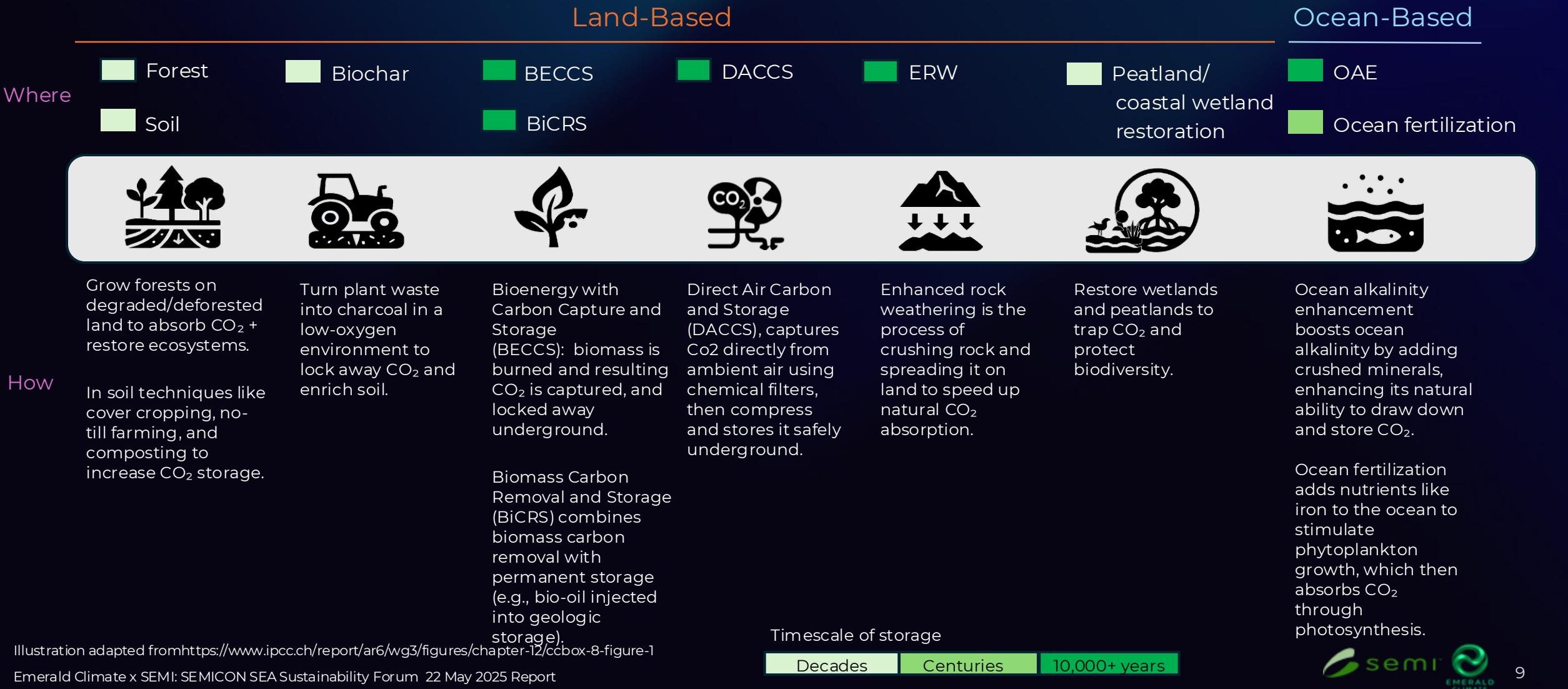


Illustration adapted from <https://www.ipcc.ch/report/ar6/wg3/figures/chapter-12/ccbox-8-figure-1>

Sustainability Forum

22 May 2025, Thursday
09:30 - 16:15hrs
L3 | Cassia | 3777



Rueban Manokara

Global Lead, Carbon Finance
& Markets Taskforce



Harris Cohn

Head of Sales

CHARM



Huey Lin

Special Projects
Senior Advisor

Terraformation



Zech Lung

Operations Lead

arukah



STRONG
TOGETHER

Harnessing Reforestation and Biomass - Strategic and Scalable Pathways for Southeast Asia



"Scaling carbon removals is not just a climate need. It must be done in a way that delivers lasting benefits for people and nature."

Rueban Manokara
Global Lead, Carbon Finance & Markets Taskforce
WWF

- a. *"Biochar at scale can significantly impact agrifood productivity and climate in the region. Focusing on rice in Southeast Asia alone, from 170 million tons of waste annually, we have the potential to sequester over 1 billion tons of CO₂ over a decade and generate more than \$100 billion in new climate income for farmers through high-quality biochar projects."*
- b. Joanna Yeo
- c. CEO & Founder
- d. Arukah

Trust, Durability, Community. Pillars for a resilient carbon removal market.

Trust as foundation:

High-quality Measurement, Monitoring, Reporting, and Verification (MMRV) must be:

- Digital
- Traceable
- Aligned across methodologies

Presenting a major opportunity for semiconductor-linked standards innovation.

Durability through risk mitigation:

- Tropical low-risk zones
- Active community consultations & equitable benefit sharing mechanism
- Building biodiversity

De-risks long-term CDR supply by engaging local communities as a frontline defense against ecosystem threats.

Communities as stakeholders:

- Local reinvestment
- Job creation
- Circular land regeneration

Unlocks stable project pipelines and social license, important for semiconductor supply chains seeking ESG credibility.

Carbon markets as a catalyst:

Early credit revenue funds innovation and unlocks co-products like:

- Lower carbon fuels
- Carbon-negative industrial inputs

New industrial models the chip industry can help scale to replace legacy polluters.



Forest

Terraformation Restores Native Forests

16 Countries
24 Projects
100% Native species (excluding agroforestry systems)

2.4M Total Plants Planted
4 Awards received
2020 Year founded
80 Team members



INTEGRATED OFFERINGS INCLUDE

Forestry expertise with in-house restoration staff
Proprietary software and solutions
Local capacity building & seed banking
Access to capital via carbon credit market



Terraformation

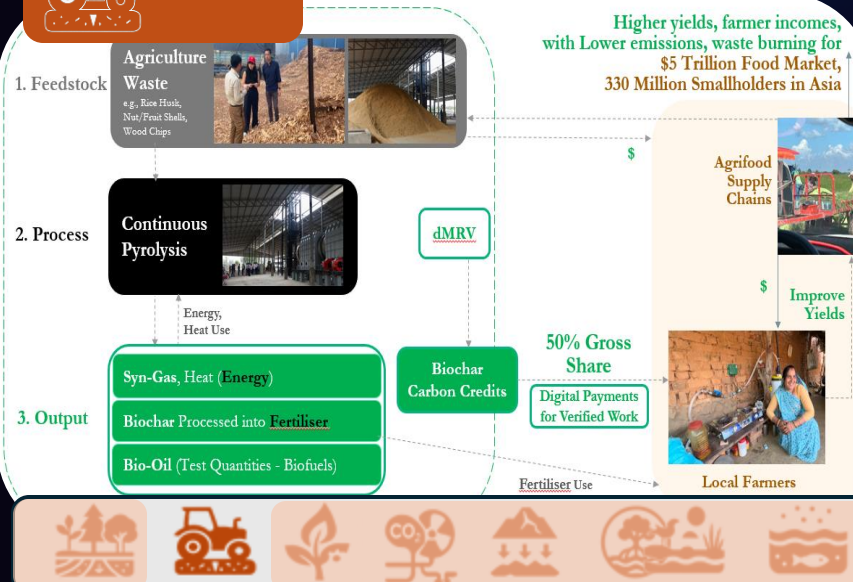
Creates scalable solutions through a seed-to-carbon forest accelerator that empowers communities to tackle the climate crisis while turning degraded lands into carbon assets. Its tracking software, Terraware, provides visibility from seed to nursery to planting and is used by more than 700 organizations across 90 countries.

Arukah

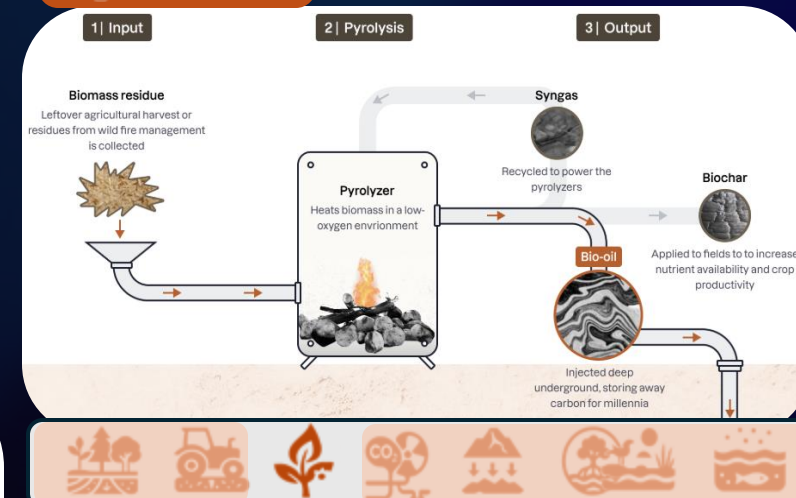
Arukah, an agriwaste-to-value company, empowers farmers through carbon removal. Converting agriculture and livestock waste to biochar and biogas to sequester carbon, generates renewable energy and organic fertilizer, and unlocks new income for farmers. Digital MRV with per-farmer traceability ensures transparent compensation from work to payment.



Biochar



BiCRS



Charm Industrial

Uses pyrolysis to convert biomass to stable, carbon-rich liquid that can be permanently stored underground, preventing wildfires and soil erosion.



Forests |



Soil |



Biochar |



BECCS |



BiCRS |



DACCS |



Enhanced rock weathering |



Peatland + coastal wetland |



OAE + Ocean fertilization

Highlight shows the active carbon removal method featured on this slide

Fireside Chat



Edwin Zeng

Business Development
Manager



Sylvia Low

Director
Business Development



Panel



Stephanie Duran

Co-Founder



Edward Sanders

Chief Executive Officer



Dr. Leo Park

Vice President
Strategic Development



Clearing the Air and Rebalancing the Ocean

“Asia’s rapidly growing desalination sector—led by innovation hubs like Singapore—offers a unique opportunity to capture CO₂, recover more freshwater, and minimize brine discharge all at once, turning a climate challenge into a circular solution.”

Leo Hyoungkun Park, Ph.D.
VP, Strategic Development
Capture6

“Investing in carbon removal is more than an environmental responsibility—it's a strategic business move.”

Christoph Gebald
Co-Founder & Co-CEO
Climeworks

1PointFive

Developing Carbon Capture, Utilization and Sequestration (CCUS) solutions, including Carbon Engineering's Direct Air Capture and AIR TO FUELS™ solutions alongside geologic sequestration hubs.



Climeworks

A Direct Air Capture pioneer with over 15 years of experience and 150,000 operational hours, Climeworks operates the world's first and largest commercial Direct Air Capture plants, Orca & Mammoth. Recognized with the industry's only "AAA" carbon removal rating, Climeworks delivers permanent, high-quality CO₂ removal at scale and offers a holistic carbon removal portfolio platform to ensure immediate climate benefits alongside scalable innovations for the future.*

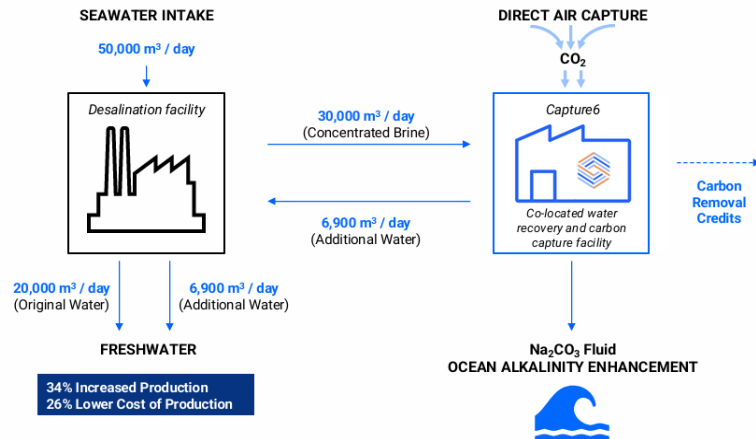
Forests | Soil | Biochar | BECCS | BiCRS | DACCS | Enhanced rock weathering | Peatland + coastal wetland | OAE + Ocean fertilization

Highlight shows the active carbon removal method featured on this slide

*Due to technical issues, we were unable to link Climeworks into the panel discussion
Emerald Climate x SEMI: SEMICON SEA Sustainability Forum 22 May 2025 Report



Capture6's technology can increase water production by ~35% and reduce costs by ~26%

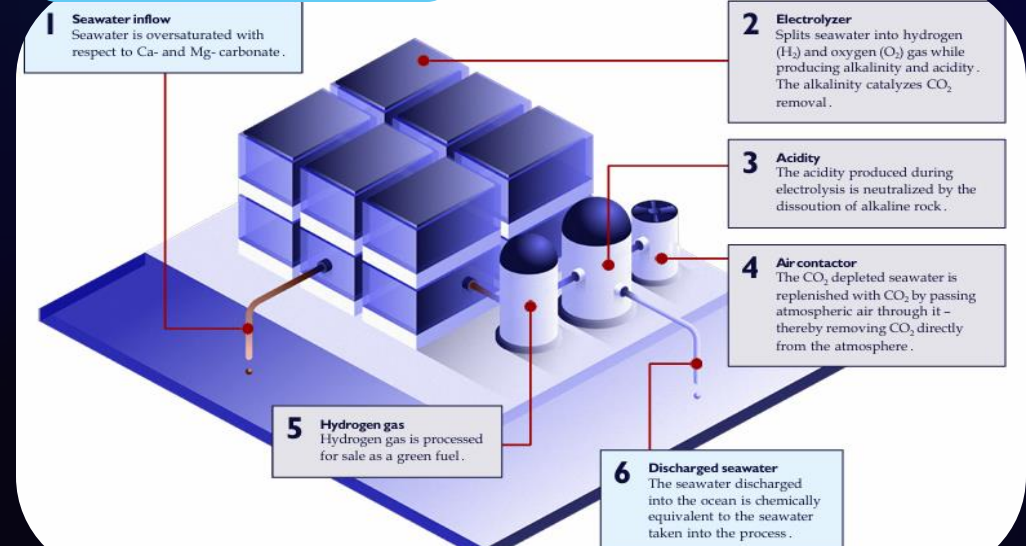


Equatic

Atmospheric carbon dioxide capture and green hydrogen production through seawater electrolysis



Equatic



CAPTURE6

Water positive carbon removal that can simultaneously reduce and remove carbon, bringing co-benefits (e.g., water production) for communities and the environment

Forests | Soil | Biochar | BECCS | BiCRS | DACCS | Enhanced rock weathering | Peatland + coastal wetland | OAE + Ocean fertilization

Highlight shows the active carbon removal method featured on this slide

A durable, integrated platform enables flexibility

CO₂ utilization promotes circularity with lower carbon fuels and products.

CO₂ sequestration, captured through point-source and Direct Air Capture, broadens addressable markets at different sections along the supply chain and improves project bankability.

Direct Air Capture carbon removal allows sectors with hard-to-abate emissions to be addressed.



1PointFive's Stratos Direct Air Capture plant in Texas

“Our strength is the ability to toggle between different product lines. Each product generated is mutually exclusive as each ton of CO₂ removed is uniquely attributed to only one end-product”

- Sylvia Low, Director of Business Development, 1PointFive

The importance of industrial co-location, co-product value chains, and public-private coordination are key to scaling carbon removal in dense, high-demand regions

Co-product business models unlock new industrial value chains

- **Freshwater production** through desalination of brine supports operations in water-stressed regions
- **Hydrochloric acid recovery** delivers operational and environmental benefits for semiconductor manufacturing
- **Green hydrogen integration** enables dual-revenue streams with synergistic climate and industrial gains
- **Urban- and industry-friendly formats**, low land footprint, vertical integration, align with high-density regions like Singapore

CDR cost reduction may be possible when paired with co-products

- **Understanding the business case for investing** in CDR can translate into a diversified and dynamic carbon credit strategy, helping reduce market risk and accelerate scale-up
- **In-house offtake & procurement** reduces market risk and accelerates scale-up
- **Industrial co-location** (e.g., near fabs, chemical plants, or utilities) optimizes infrastructure and shared resources
- **ISO-certified MMRV systems** ensure traceability and builds trust

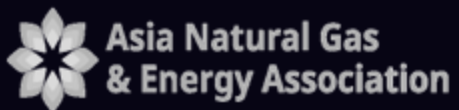
Scaling requires cross-border deployment models and policy innovation

- **Geopolitical risk** is prompting developers to diversify into Southeast Asia and the Middle East
- **Public-private alignment** (e.g., California CDR grants, Korea R&D support, IRA 45Q tax credits) crucial for first-of-a-kind projects)
- **CO₂ storage innovation** expanding from saline formations and depleted coal mines to ocean-based carbonates
- **Holistic carbon removal portfolio platform** combines high-impact nature-based solutions already delivering results with breakthrough technological approaches



Hanh Le

Senior Advisor



Stephanie Duran

Co-Founder



Cindy Lim

Chief Executive Officer, Infrastructure



Key Enablers for CDR Deployment

“We want to bring along the ecosystem... because many times, decarbonization technology requires end-to-end value chain play. This is where we see Keppel playing a force multiplier role.”

Cindy Lim
Chief Executive Officer, Infrastructure
Keppel Ltd.

Fireside chat with Cindy Lim: Key enablers in Singapore

Powering Singapore's transition: Keppel's role & innovations

Keppel's three hat role in decarbonization

1. Generator

Power generation and retail electricity

2. Solution provider

Support to Singapore's "four switches" strategy for energy transition

3. Force multiplier

Building ecosystem partnerships for scalable and bankable low-carbon technologies

Spotlight on innovation



Energy
innovation



Environmental
sustainability in
waste and water
treatment



Smart grid



InfraTech

Next-gen, hydrogen-ready power:

Keppel is deploying Singapore's most efficient gas turbine (H-class), cutting CO₂ emissions by up to 15% and enabling 30% hydrogen blending for future-proofed, low-carbon power.

Energy-as-a-service for decarbonization:

Keppel is pioneering long-term energy procurement models that bundle power, cooling, and emissions reductions tailored to help industrial partners meet net-zero targets.

Keppel's decarbonization strategy: Enabling Singapore's low-carbon future

Energy "Trifecta" vs. Trilemma

- Energy "trifecta" vs. traditional "trilemma" means pursuing optimization rather than trade-offs across sustainability, security, and affordability.
- Advanced planning and integrated design are key in future plants.
- Co-locate carbon capture facilities with power generation from natural gas and waste-to-energy in Singapore, capturing CO₂ emissions at the source.

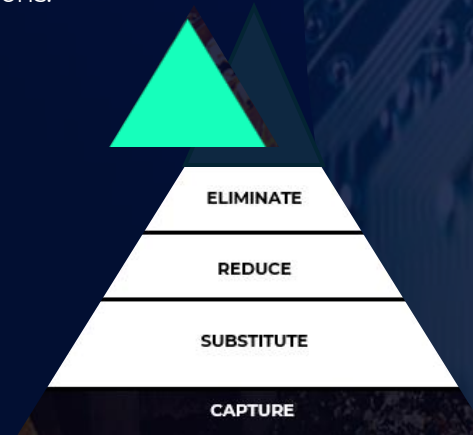
SUSTAINABILITY

SECURITY

AFFORDABILITY

Carbon management strategic approach

Carbon management hierarchy eliminate, reduce, substitute, and capture remaining emissions.



Carbon Capture and Storage (CCS)



Land constraints in Singapore and lack of storage means cross-border collaboration is needed.



CCS requires policy clarity, risk-sharing, and public-private partnerships.



Cross-border negotiations need emphasis on community engagement with regional equity a prime consideration in framing.

ANGEA cross-border CCS study highlights

Five core elements for effective cross-border CCS bilateral agreements

Data sharing protocols
(for certification
and MMRV)



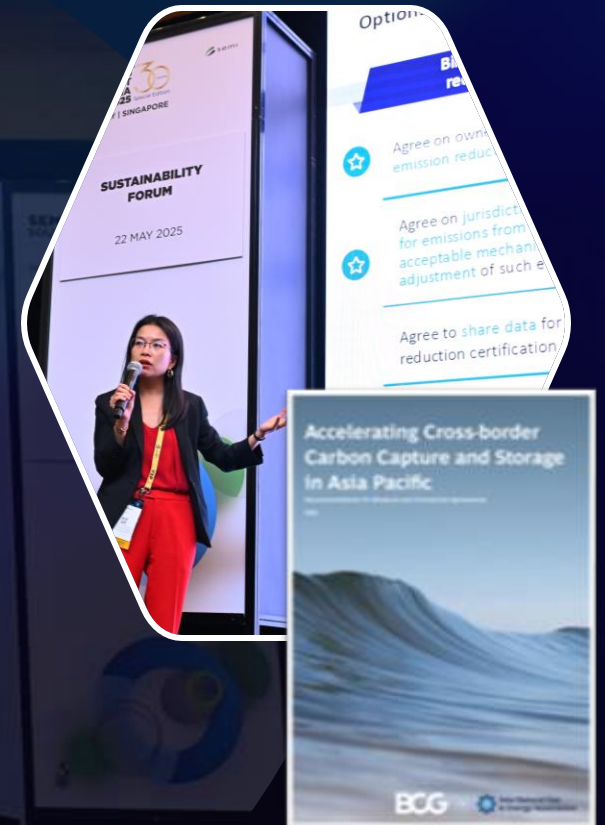
Liability handover
points (border,
terminal, or injection)

Ownership rights for
emission reductions

Dispute resolution
mechanisms

Responsibilities in
international CO₂
transport, especially in
third-party waters

Governments have different options under each of these elements, allowing flexibility to reflect national circumstances. Governments can adopt arrangements that are **low-cost, simple, practical, and robust**, ensuring sustainable transport within this emerging value chain.



ANGEA's cross-border CCS report can serve as a foundation for regional CDR deployment

Cross-Border Infrastructure & Governance

- Cross-border storage is essential for regional decarbonization, including carbon removal.
- Address CO₂ transport rules, including third-party waters.
- Enable cross-border data sharing for certification and storage verification.
- Leverage ANGEA's bilateral framework to shape CDR agreements.

Market Integrity & Accounting

- Clarify carbon credit ownership models for DACS (Article 6.2, voluntary markets).
- Ensure no double counting through robust accounting (essential for high-integrity CDR markets).
- Align MMRV with ISO/IPCC standards to ensure permanence and market trust.
- Define liability handover points in future DACS pilot agreements.

Policy & Market Development

- Leverage early policy support to de-risk infrastructure, attract international climate finance.
- Allow claiming and trading flexibility for removals supporting both NDC-aligned and voluntary claims.



Alvin Lee

Head of Supply



Hanbin Lim

Deputy Director, APAC
EHS & Sustainability



Bess Ng

Associate Principal,
Sustainability Business



Marshall Chase

Director of
Sustainability



Genevieve Ding

Former Head of Carbon
Credits & NBS APAC



From First Movers to Fast Followers - Chain Reaction Across the Semiconductor Industry



“ Market isn’t created overnight. We need to help seed the demand signal to provide catalytic support for the nascent market...”

Bess Ng
Associate Principal, Sustainability Business
Scheider Electric

The speakers recognized carbon removal's role, barriers, gaps and near-term opportunities.

Accounting frameworks require clarification regarding hard-to-abate scope 1 emissions

- Long-lived F-gases (e.g., CF₄) **more potent than CO₂**.
- Traditional carbon accounting (GWP100) **underrepresents** these gases at longer time scales.
- **Need for widely-recognized norms and standards** for CDR offsets of long-lived F-gases.

High-cost and low-confidence in CDR supply prevents adoption

- Significant **financing gaps**, especially for tech-based solutions.
- Demand for blended finance and **public-private** instruments to close the funding gap.

Regional market fragmentation and lack of standards for MMRV

- **Concerns** over quality assurance, durability, and lack of harmonized certification standards.
- Cross-border collaboration is essential.

Energy access a major barrier, particularly in the APAC region

- **Electricity availability** (difficult to source in Singapore).
- **High-cost** of electricity in some markets (e.g., Taiwan).

CDR an effective tool for residual offsets, complementing not replacing reductions – the question is when.

Learning from the leaders: carbon removal in motion

Amazon (First Mover)

-  Climate pledge: Net-zero carbon across operations by 2040
-  Largest global corporate buyer of renewable energy to address Scope 2
-  Carbon removal strategy prioritizes:
 - Tropical forest protection
 - Land restoration
 - Scalable tech-based removals (e.g., DACCS)
-  Catalytic off-taker: signs long-term carbon credit contracts to de-risk early-stage CDR
-  Market builder: Extends credit access to customers and suppliers to drive broader ecosystem adoption

Schneider Electric (Fast Follower)

-  Net-zero commitment: ~90% reduction in Scope 1 & 2 emissions paired with CDR by 2030
-  Full net-zero (Scopes 1–3) plus carbon removals for residuals by 2050
-  Carbon removal strategy:
 - Guided by SBTi principles
 - Mix of nature-based and engineered removals, with a gradual shift toward tech-based solutions
-  First procurement begins in 2025 to meet 2030 targets

Where policy meets procurement

Challenges

- CDR strategies for hard-to abate/ residual emissions
- Limited access to renewables
- Unclear accounting frameworks, particularly for fluorinated gases (F-gases)
- High cost, low confidence in scale of CDR suppliers
- Fragmented MMRV & registries
- Disparate ASEAN markets

Opportunities

- Define sector-specific CDR offset rules aligned with SBTi + SEMI
- Evaluate CDR to bridge residual Scope 2 in constrained grids
- Sandbox F-gas carbon equivalency to better clarify global warming potential (GWP)
- Test blended finance & buyer coalitions to de-risk procurement
- Pilot regional interoperability
- Coordinate procurement through Singapore as anchor in ASEAN Carbon Market

What's next



SEMICON® INDIA

September 2-4, 2025

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SEMICON® INDIA

BUILDING THE NEXT SEMICONDUCTOR POWERHOUSE

SEP 2 - 4, 2025 | YASHOBHOOMI (IICC), NEW DELHI

SEMI and **Emerald Climate** are gearing up for a 2026 CDR pilot procurement, reach out to us for more details

Pauline@emeraldclimate.co
Stephanie@emeraldclimate.co

About Emerald Climate

Strategic convener



Organize and align key stakeholders under one coordinated effort. Build bridges between government, industry, tech, and finance sectors.

Singapore-based advisory



Drive projects to close while unlocking corporate demand and building the CDR market in partnership with Singapore government. Focus on demonstration, procurement, and project curation.

Trusted delivery partner



Serve as the anchor partner of the SEMI Buyers' Coalition . Act as the facilitator for buyers, suppliers, governments, and funds. Serve as a resource for SEMI member companies on CDR.