New Business Opportunities from Carbon Neutral & How DL E&C-CARBONCO Approaches

15 Jun 2023
Sang-il Kim
General Manager, Head of Sales & Marketing Team I
Speaker Profile

Sang-il Kim

CARBONCO Pte. Ltd
General Manager, Head of Sales & Marketing Team I

- 17 years of experience in business development, sales & marketing, and project execution in petrochemical sector and power generation sector
- Executed 1,000 MW CFPP project as Project Control Manager, and Sales & Marketing Manager of DL E&C
- Leading the project development teams tasked with the business of CCUS, Clean Hydrogen and Ammonia in CARBONCO
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  - Carbon Capture, Utilization, Storage
  - Ammonia/Hydrogen
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- Project Cases Studies
  - Case 1: Coal-Fired Power Plant “CCU” Project
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Limiting Global Warming to 1.5°C

Over 190 nations and multinational companies have voluntarily agreed to reach net zero by 2050 to minimize irrecoverable climate damages by reaching net zero carbon emission and limiting global warming to 1.5°C above pre-industrial level.

### Impacts from 1.5°C vs. 2.0°C Temperature Rise

<table>
<thead>
<tr>
<th>Category</th>
<th>Impact</th>
<th>1.5°C</th>
<th>2.0°C</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Impacts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme Heat</td>
<td>Exposure to sever heat at least once every five years</td>
<td>14%</td>
<td>37%</td>
<td>3x</td>
</tr>
<tr>
<td>Sea-Ice-Free Artic</td>
<td>Number of Ice free summers Every 100 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea-level Rise</td>
<td>Amount of sea level rise by 2100 0.40m 0.46m</td>
<td></td>
<td></td>
<td>+0.06m</td>
</tr>
<tr>
<td><strong>Species</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertebrates</td>
<td>Vertebrates that lose at least half of their range</td>
<td>4%</td>
<td>8%</td>
<td>2x</td>
</tr>
<tr>
<td>Plants</td>
<td>Plants that lose at least half of their range</td>
<td>8%</td>
<td>16%</td>
<td>2x</td>
</tr>
<tr>
<td>Insects</td>
<td>Insects that lose at least half of their range</td>
<td>6%</td>
<td>18%</td>
<td>3x</td>
</tr>
<tr>
<td><strong>Land</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecosystems</td>
<td>Land where ecosystems shift to a new biome</td>
<td>7%</td>
<td>13%</td>
<td>2x</td>
</tr>
<tr>
<td>Permafrost</td>
<td>Artic permafrost that will thaw 4.8Mkm 6.6Mkm</td>
<td></td>
<td></td>
<td>38%</td>
</tr>
<tr>
<td>Crop Yields</td>
<td>Reduction in maize harvest in tropics 3% 7%</td>
<td></td>
<td></td>
<td>2x</td>
</tr>
<tr>
<td><strong>Oceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coral Reefs</td>
<td>Decline in coral reefs &gt;70% 99%</td>
<td></td>
<td></td>
<td>&gt;29%</td>
</tr>
<tr>
<td>Fisheries</td>
<td>Decline in marine fisheries 1.5Mt 3.0Mt</td>
<td></td>
<td></td>
<td>2x</td>
</tr>
</tbody>
</table>

- **Greenhouse gas ("GHG") emissions** has skyrocketed since the industrial revolution, causing global warming and climate change
  - Land and ocean temperature has increased on average of 1.04°C
  - Atmospheric carbon dioxide concentration are 50% higher

- **As a global initiative to mitigate future climate damages**, 194 nations have signed 2015 Paris Agreement to reduce GHG emissions to net zero by the second half of the 21st century
  - The signed countries represent over 98% of global GHG emissions as of September 2022
  - Every five years, each country is expected to submit an updated Nationally Determined Contribution (“NDC”), which outlines strategic pathway towards net zero

Source: Climate Council, IPCC
Progress for Net Zero is falling Behind

Announced GHG mitigation measures such as electrification are insufficient to meet the net zero requirements. To bridge the gap, CCUS technology is expected to play an essential role by reducing net carbon emissions for carbon-intensive industries.

**Required CO₂ Reduction by Technology: Net Zero vs. Stated Policy**

- **2030 NDC Target**
  - EU: 55% (compared to 1990)
  - UK: 68% (compared to 1990)
  - USA: 52% (compared to 2005)
  - Canada: 45% (compared to 2005)
  - Japan: 46% (compared to 2013)
  - South Korea: 40% (compared to 2018)

- **~ 2050**
  - EU: 67%
  - UK: 67%
  - USA: 56%
  - Canada: 56%
  - Japan: 46%
  - South Korea: 40%

Source: Climate Action Tracker, IEA

1. CO₂ reduction by measures from IEA are adjusted pro rata to the emission gap between the expected emission and warming are based on median value for Policies & Actions (based on current policies) and 1.5°C compatible benchmark developed by Climate Action Tracker.

Source: ROK Government Report 2021
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Net Zero scenario requires the current global CCUS project pipeline to be ramped up nearly five-fold and annual investment to reach US$100bn by 2030.

**CO₂ Capture Capacity: Project Pipeline vs. Net Zero**
(Mtpa)

- **Current/Planned Pipelines**
  - 2022: 44
  - 2023: 51
  - 2024: 74
  - 2025: 148
- **Net Zero Scenario (IEA)**
  - 2030: 265
  - 2040: 5,619
  - 2050: 7,603

**Addressable Market**
(Annual CO₂ capture capacity)

- **7.6Gtpta by 2050**
- **1.3Gtpta by 2030**

- CCUS may be the only economically viable solution for carbon reduction in hard-to-abate sectors such as cement, steel and chemicals, that are facing more imminent regulatory warming and climate change.
- Fossil fuel including coal, natural gas and oil accounts for >60% of the required CO₂ capture capacity in 2050.
  - The remaining 40% are from industrial process, biomass, oil/gas and direct air capture.

Source: Global CCS Institute, Company disclosure, News run
Industrial sectors are the major carbon emitters, accounting for total 24.9% of the total CO₂ emission, led by iron, steel and cement production.

**Annual CO₂ Emission by Sector**

**Absolute CO₂ emissions and CO₂ emissions intensity**¹

- **Cement** production and iron & steel production are one of the largest industrial emitter of carbon which accounts for 6.9% and 7.4% of total CO₂ emissions in 2021, respectively.

- **Cement** functions as a key input to manufacturing concrete production as a binder between aggregates and has the highest carbon emission intensity amongst industrial materials.

Sources: IEA, McKinsey, News run

¹ CO₂ emission intensity is calculated based on 2017 McKinsey report and adjusted pro rata up to 2021 by reflecting growth rate by sector from IEA
CCUS market is one of the fastest growing markets with positive outlook that is forecasted to reach the size of US$4tn by 2050 on a global basis.

1. **Supportive Government Policies**
   - 48 jurisdictions implemented or have plan to implement carbon pricing instruments to that can potentially improve profitability of CCUS projects and overcome the green premium
   - CCUS projects are further benefited by favorable policies such as carbon tax, ETS and CCUS de-risking mechanism including contracts-for-difference, incentives and grants

2. **Development of Value Chain and Project Pipeline**
   - Increasing number of industry participants are filling gaps across the CCUS value chain, making the industry more robust and driving momentum for new projects
   - Large capital is flowing into CCUS as industry leaders embrace CCUS as a critical solution to achieve Net Zero by 2050

3. **Improvement in Project Economics**
   - Governments and companies across the globe are collaborating to launch larger-scale CCS projects and expand relevant infrastructures to alleviate bottlenecks and improve economics
   - CCS operation costs are also drastically decreasing due to maturing technologies across the CCUS value chain and scale of economies backed by forward-looking industrial tailwind

4. **Technological Development**
   - Carbon capture and transportation technologies have matured and commercialized through decades of investment and experiences, largely driven by players in the oil and gas industry
   - In order to facilitate the deployment of CCUS solution, there is a growing emphasis on directing R&D support and investment towards carbon utilization and storage technologies to develop economically viable captured CO₂ treatment solutions

Source: Exxon Mobil, Energy Transition Commission, IEA, News run
CCUS industry may benefit from increasing number of countries that announce more advanced net zero pledges and decarbonization roadmaps, which will form favorable political landscape.

<table>
<thead>
<tr>
<th>Major Countries</th>
<th>Net Zero Target Year</th>
<th>Legal Status</th>
<th>Net Zero Policies</th>
<th>GHG Emission in 2021 (MtCO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Pre-2060</td>
<td></td>
<td>14th Five-Year Plan which outlined plans to increase share of non-fossil share of electricity generation to c.39% by 2025</td>
<td>11,939</td>
</tr>
<tr>
<td>United States</td>
<td>2050</td>
<td></td>
<td>Enacted the Inflation Reduction Act which includes US$369bn in funding for climate energy</td>
<td>4,551</td>
</tr>
<tr>
<td>EU</td>
<td>2050</td>
<td></td>
<td>Outlined “Fit for 55” package including to increase for the share of renewables in energy consumption from 32% to 40% by 2030</td>
<td>2,658</td>
</tr>
<tr>
<td>India</td>
<td>2070</td>
<td></td>
<td>Released the Draft National Electricity Plan highlighting a plan for renewables</td>
<td>2,537</td>
</tr>
<tr>
<td>Russia</td>
<td>2060</td>
<td></td>
<td>Released the Transport Strategy Until 2030 including measures for energy-efficient or electric vehicles, low-carbon infrastructure, etc.</td>
<td>1,860</td>
</tr>
<tr>
<td>Japan</td>
<td>2050</td>
<td></td>
<td>G7 members including Japan agreed to decarbonize electricity by 2035 and to end fossil fuel subsidies by 2025</td>
<td>1,039</td>
</tr>
<tr>
<td>Iran</td>
<td>N/A</td>
<td></td>
<td>Iran expressed its intention to modify national laws and policies to reform energy consumption patterns during COP26</td>
<td>681</td>
</tr>
<tr>
<td>Korea</td>
<td>2050</td>
<td></td>
<td>Announced the 10th Electricity Plan setting share of renewable energy to c.23.3% by 2030</td>
<td>600</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>2000</td>
<td></td>
<td>Promoting the concept of a Circular Carbon Economy (CCE) to reduce emissions from oil and gas production</td>
<td>562</td>
</tr>
<tr>
<td>Canada</td>
<td>2050</td>
<td></td>
<td>Revised 2030 Emissions Reduction Plan to accommodate its enhanced Paris Agreement Target to reduce emission by c.40% from 2005</td>
<td>540</td>
</tr>
<tr>
<td>Australia</td>
<td>2050</td>
<td></td>
<td>Released its Long-Term Emissions Reduction Plan to achieve net zero emissions by 2050 through a green technology-led approach</td>
<td>352</td>
</tr>
</tbody>
</table>

Source: Climate Action Tracker, European Commission, IEA, News run
Hydrogen is the only renewable energy source with stable supply that can replace fossil fuel across wide spectrum of industries and will play a central role in achieving net-zero emissions by 2050.

**Overview**

- **Hydrogen is mainly used for chemical feedstock and as a low-carbon energy fuels**
  - Hydrogen is predominately utilized as a feedstock for oil refining, ammonia production for fertilizer, methanol production and steel production
  - Application as low-carbon energy fuels includes transport and power generation, in which still requires further technological advancement for wider adoption

- **Hydrogen’s value as a versatile solution lies in its potential to play a significant role in decarbonization of hard-to-abate sectors where carbon abatement solutions are challenging to be implemented**
  - Hydrogen is a low-carbon energy source, with water being the only by-product produced during energy transition processes
  - Hydrogen offers a stable supply and mobile applications through fuel cell technology

- **Hydrogen can currently be produced in multiple forms, ranging from grey (fossil fuels), blue (fossil fuels + CCS) and green (renewable energies), offering a range of options for sustainable energy production**

Net zero scenario projects hydrogen to be globally adopted for decarbonization of hard-to-abate sectors, such as steel, cement and chemicals, that are not readily be electrified.

Global Hydrogen Demand by Segments
(Mtpa)

Addressable Market by 2050
(CO₂ capture capacity per annum, unless specified otherwise)

- Hydrogen is expected to play a critical role in achieving carbon neutrality as a versatile and scalable energy fuel/vector with a cumulative abatement of 80GtCO₂ by 2050
- >60% of the hydrogen demand will be supplied through long distance transport such as international cross-border and domestic long-distance transportation in 2050

Sources: Global CCS Institute, Company disclosure, News run
Securing core technical capability related to hydrogen at early stage would be a key as global transition to hydrogen economy is inevitable but would require improved cost competitiveness and technology developments.

Why Hydrogen?

1. Wide Range of Application
   - Hydrogen can be utilized as chemical feedstock and fuel in a range of sectors
   - Offers decarbonization solutions in hard-to-abate sectors where it is challenging to implement abatement solution

2. Stable Supply
   - Most abundant element in the universe with a quasi-infinite supply
   - Free from seasonal fluctuations and associated power intermittency

3. High Energy Efficiency
   - Suitable for mobility due to high energy capacity per unit fuel weight
   - Hydrogen fuel cells offer higher efficiency up to c.65% vs. 35% from fossil fuel-based generators

4. Mobile & Transportable
   - The only renewable power source that can be efficiently stored and transported in various forms, scales and methods

Sources: Hydrogen Council, McKinsey, IEA, IRENA, broker report
Hydrogen covers a wide spectrum of industries from production to end applications, providing opportunities to diverse industry participants.

**Sources:** Hydrogen Council, IRENA, IEA
Hydrogen related technologies are evolving rapidly, projecting strong potential for improved affordability and accessibility across future hydrogen value chain.

Sources: Hydrogen Council, Element Energy for BEIS, DOE Hydrogen Production Roadmap, News run
As production technology matures, hydrogen demonstrate strong momentum and growth potential to become a multi-trillion dollar market across the globe.

Overview

- Hydrogen adoption is expected to grow as hydrogen-based technologies mature and scalability improves.
- As of Nov 2022, 140 countries have announced net-zero targets, and 26 countries have committed to adopt hydrogen as a clean energy vector in their national energy system.
- As of May 2022, over 680 large-scale hydrogen projects have been announced globally with a focus on industrial usage and transport projects:
  - 80% of the project pipelines announced full or partial commissioning before 2030.
  - The total number of project announcements increased by 146 since end of 2021, demonstrating a strong industry momentum.
  - The number of giga-scale production and large-scale projects industrial usage\(^1\) has increased from 51 to 61 and 262 to 332, respectively.

Projected Global Hydrogen Production (Mtpa)

By 2050, majority of hydrogen will be green hydrogen from renewable energy sources, but blue hydrogen will play an essential role during the transition period.

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1. Giga-scale project is >1 GW or >200 kiloton p.a. of hydrogen production capacity; large-scale project is >1 MW or equivalent.
Due to its high energy density, hydrogen can be efficiently transported and stored at large-scale. This makes hydrogen the most prominent renewable energy source for sectors that are hard to be electrified due to with high energy requirements.

Energy per Unit Mass by Fuel Source (MJ/kg)

- Hydrogen
- LNG
- Natural gas (ambient)
- Methane
- Conventional Gasoline
- Propane
- LPG
- Crude Oil
- Diesel
- Ethanol
- Hard black coal
- Methanol
- Lignite/brown coal

Source: DOE, IEA, World Nuclear Association, broker report, News run

- Hydrogen is the fuel source with the highest energy per unit mass, which is more than two times than those of diesel or gasoline.
- Hydrogen fuel cell systems can generate electricity with an efficiency of up to 60%, which is significantly higher than the 33% to 35% efficiency of conventional combustion-based energy sources.
Ammonia’s superior energy efficiency and existing port and shipping infrastructure could enable the deployment of large-scale transportation of ammonia as a hydrogen carrier.

### Major Types of Hydrogen Transportation Options

<table>
<thead>
<tr>
<th></th>
<th>Compressed Hydrogen</th>
<th>Liquefied Hydrogen</th>
<th>Chemical Carrier</th>
<th>Ammonia (NH₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density (kg/m³)</strong></td>
<td>39</td>
<td>70.8</td>
<td>769</td>
<td>682 (1 bar)</td>
</tr>
<tr>
<td><strong>Hydrogen content</strong></td>
<td>100</td>
<td>100</td>
<td>6.16</td>
<td>17.8</td>
</tr>
<tr>
<td><strong>Extraction Temperature</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>200-400</td>
<td>350-900</td>
</tr>
<tr>
<td><strong>Energy Density (to H₂)</strong></td>
<td>h463</td>
<td>h865</td>
<td>h574</td>
<td>h1,467</td>
</tr>
<tr>
<td><strong>Required Infrastructure</strong></td>
<td>N/A</td>
<td>Facility investment required</td>
<td>Compatible with existing oil &amp; gas infrastructure</td>
<td>Compatible with existing propane infrastructure</td>
</tr>
</tbody>
</table>

**Pros**
- Low CAPEX
- Low conversion loss
- Storage stability
- Compatibility
- Long-term storage
- Compatible with propane infrastructure
- High energy density

**Cons**
- Safety and cost of transportation
- Low energy density
- Safety and cost of transportation
- Cost of liquefaction
- Cost and scalability
- Efficiency of chemical processes
- Odour
- Toxicity
- Conversion losses

Sources: Hydrogen Council, Royal Society, broker reports, News run

A Heat Map of Liquid Ammonia Carriers and Existing Ammonia Port Facilities

- The ammonia storage and transport infrastructures exist extensively across the globe to supply feedstock for inorganic fertilizers production
- As ammonia is compatible with propane infrastructure, retrofitting and repurposing of existing propane infrastructure present significant opportunity to expand the infrastructure networks as a hydrogen carrier
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DL Group boasts a dazzling catalog of multiple landmark projects globally and domestically, including the world’s largest ammonia production plant in Saudi Arabia.

**DL Group Overview**

- Founded in 1939, DL Group was the first domestic construction company in Korea and grew to become a diversified conglomerate with an extensive global presence in 40+ countries.

- DL E&C is one of Asia’s leading EPC contractor for companies in the petrochemical, power, energy, housing and civil works industries.
  - DL E&C has completed >600 projects in 35 countries around the world with >49 years of experience in plant design and engineering.

- CARBONCO was formed to address the growing need for decarbonization solutions.
  - Only Korean company able to provide full scope EPC services for commercial scale CCUS projects.
  - Oversaw the first carbon capture pilot plant project in Korea.

**DL Group Structure**

- DL Holding - 42.3%
  - DL Chemical - 11.1%
  - DL E&C - 23.2%
  - DL Energy - 70.0%

- DL E&C
  - DL Construction - 63.9%
  - CARBONCO - 100.0%

- DL Chemical
  - DL F+X Cariflex - 100%
  - KRATON - 100%
  - PolyMirae - 50%
  - YNCC - 50%

- Petrochemical & Speciality Chemical

- Energy

- EPC & Construction
Collaboration Potential Across DL Group

There are significant strategic collaboration opportunities across the DL Group that could potentially accelerate the value creation and create significant synergies in CARBONCO’s business ecosystem.

<table>
<thead>
<tr>
<th>Company Description</th>
<th>CCS/Carbon Products</th>
<th>Hydrogen/Ammonia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DAELIM</strong></td>
<td>▪ Trading company specializing in petrochemical products, shipping and logistics services</td>
<td>▪ Logistic service for captured CO₂ by leveraging off its cross-border shipping and an extensive global network</td>
</tr>
<tr>
<td><strong>DL Chemical</strong></td>
<td>▪ Petrochemical company producing basic chemicals and synthetic resins</td>
<td>▪ Decarbonizing emitted CO₂ from chemical plants</td>
</tr>
<tr>
<td><strong>DL Energy</strong></td>
<td>▪ Energy company developing and operating a diverse power generation business, from gas combined cycle to renewable energy</td>
<td>▪ Decarbonizing emitted CO₂ from power plants across the globe</td>
</tr>
<tr>
<td><strong>DL Construction</strong></td>
<td>▪ Construction company specializing in EPC services, primarily in Korea</td>
<td>▪ Off-taker of produced recycled aggregates</td>
</tr>
<tr>
<td><strong>DL E&amp;C</strong></td>
<td>▪ Construction company specializing in EPC services for housing, civil, and plant project across the globe</td>
<td>▪ Off-taker of produced recycled aggregates</td>
</tr>
<tr>
<td></td>
<td>▪ EPC (Hub, Pipeline, Plant etc.)</td>
<td>▪ Small Modular Reactor (for pink/purple hydrogen)</td>
</tr>
</tbody>
</table>
DL Group’s 20+ Years of Monumental Track Record

DL Group boasts a dazzling catalog of multiple landmark projects globally and domestically, including the world’s largest ammonia production plant in Saudi Arabia.

**Saudi Arabia**
- Saudi Butanol / Syngas EPC (2016)
- Ma’aden Ammonia III EPC (2021)
- Ma’aden Ammonia II (2015)

**Egypt**
- Middle East Oil Refinery
- MIDOR Oil Refinery EPC (2001)

**Oman**
- Oman Green Ammonia F/S (2022~)

**Korea**
- SK E&S LNG CCUS Basic/FEED (2022~)
- SEOHAE GREEN CCUS Basic/EPC (2022~)
- KEPRI CCS 2014 Basic/FEED (2014)
- KEPRI Boryeong CCS Basic/O&M (2010)
- KEPRI Dangjin CCS EPC (2002)
- Lotte BP CO FEED (2020)
- Hyundai Chem. HPC NCC FEED (2019)
- Hyundai Oil-Bank EPC (2008~2011)

**Philippines**
- PETRON RMP II EPC (2014)

**India**
- Indian Oil Corp. Mathura Refinery EPC (1999~2005)

**Australia**
- NeuRizer Fertilizer FEED EPC (2022~)
- NeuRizer Fertilizer CCUS Basic/EPC (2023~)
CARBONCO will transition its legacy EPC-centric business model inherited from DL E&C to a developer business model, providing long-term services and supplying diversified products along the CCUS and hydrogen value chains.
Ecosystem of DL Group & CARBONCO (2/2)

Foreign Countries

- CO₂ Emitter
  - Flue Gas
  - CO₂ Sequestration
  - N/G
  - Oil & Gas Field
    - CO₂ Sequestration
    - Electricity
    - N/G
    - N/G
  - Decarbonized Power Plant (CC Integration)
    - CO₂
    - Electricity
    - N/G
    - N/G
  - SMR & Carbon Capture
  - Hydrogen → Ammonia
  - Green Hydrogen Electrolysis
  - Desalinated Water
  - Desalination Plant (RO Type)
  - Green H₂
  - Drinking Water
  - Household
  - L-CO₂ Market
    - Welding, Dry-ice, Beverage etc
  - Mineralization
    - Aggregate, CaCO₃
  - CO₂ Liquefaction
  - CO₂ Carbonization
  - CO₂

Korea

- CO₂ Emitter
  - Flue Gas
  - Electricity
  - Power Plant
    - KEPCO Subsidiary
      - (Co-development of Ammonia Cracking technology)
  - Carbon Capture Plant
  - Blue H₂ Fuel
  - Green H₂ Fuel
  - Blue/Green NH₃ Transportation
  - CO₂ Transportation
Business Model of CARBONCO

Building on an impressive legacy of 20+ years EPC track record in carbon capture and ammonia facilities, CARBONCO strives with vigorous steps to become a leader in providing solutions and developing facilities across the CCUS and hydrogen/ammonia value chains. CARBONCO aims to position itself as a leader with pioneering ideas to achieve a global goal.
CARBONCO is a total CCUS solution provider based on wide range of proprietary decarbonization technologies and strong EPC capability.

<table>
<thead>
<tr>
<th>EPC</th>
<th>Recurring Service</th>
<th>Services</th>
<th>CARBONCO Solutions</th>
<th>Description</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Plant Design Optimization</td>
<td>1 Standardisation</td>
<td>▶ Standardized plant design library for carbon capture capacity up to 3,000tpd</td>
<td>IDL E&amp;C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CCS</td>
<td>2 Modularization</td>
<td>▶ Customizable modular designs that minimizes design period and costs</td>
<td>IDL E&amp;C</td>
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<td></td>
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<td>Carbon Products</td>
<td>3 Carbon Capture Solvent</td>
<td>▶ High performance amine-based solvents for carbon capture developed by KEPCO</td>
<td>IDL E&amp;C</td>
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<tr>
<td></td>
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<td>Carbon Mineralization</td>
<td>CSA Cement</td>
<td>▶ Replaces cement limestones with coal ash residuals with low carbon footprint</td>
<td>KICAM</td>
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<td></td>
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<td>Green Aggregate</td>
<td>▶ Recycles industrial waste into green aggregates, which can be used as mine fillers and construction materials</td>
<td>KICAM</td>
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<tr>
<td></td>
<td>Hydrogen/Ammonia</td>
<td>5 Blue Hydrogen Production</td>
<td></td>
<td>▶ Chemical looping water splitting (&quot;CLWS&quot;) based hydrogen production technology developed by KEPCO</td>
<td>KICAM</td>
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<td></td>
<td>Production</td>
<td>▶ Feasibility, FEED and EPC works for coal gasification-based urea/ammonia production facility in Australia</td>
<td>Neurizer</td>
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<td></td>
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<td></td>
<td>Cracking</td>
<td>▶ Ammonia cracking process that yields high conversion rate (&gt;99%) and low cost</td>
<td>KICAM</td>
</tr>
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</table>
Carbon mineralization is currently the only scalable and economical viable solution to address intermediate demand for carbon storage and CARBONCO has secured two technologies capable of producing different carbon derivatives for construction applications.

**CARBONCO Carbon Products**

**Carbonate Mixture (Calcium Carbonate)**
- Can be utilized as abandoned mine filler and construction materials
- Feedstocks include industrial waste, such as coal ash and steel slag

**CSA Cement (Calcium Sulfoaluminate)**
- Replaces limestone with coal ash residues in cement
- Reduces hardening times and improves shrinkage compensation compared to Portland cement

1. Recycled concrete aggregate
Korean government announced national hydrogen economy roadmap, targeting 5.3Mtpa hydrogen production capacity by 2040. CARBONCO has partnered with KEPCO to co-develop CLWS-based blue hydrogen production technology to preemptively secure the market leadership.

**Process Overflow**

- **Reactants**
  - Steam (H$_2$O)
  - Coal
  - Fossil Fuel (CH$_4$, CO/H$_2$)

- **Process**
  - Oxidizer Reactor
  - Reducer Reactor
  - Combustor Reactor

- **End-use**
  - Power Generation
  - Fuel Cell Vehicles
  - Fuel Cell

- **CLWS-based process produces high-purity blue hydrogen without separate carbon capture facility**

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<table>
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<th>Companies</th>
<th>Details</th>
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<td><strong>CARBONCO</strong></td>
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<tr>
<td><strong>KEPCO</strong></td>
<td></td>
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<tr>
<td><strong>Key Partners</strong></td>
<td><strong>The Ohio State University</strong></td>
</tr>
<tr>
<td><strong>System Configuration</strong></td>
<td>Coal gasification &amp; CLWS</td>
</tr>
<tr>
<td><strong>Reaction Stage</strong></td>
<td>3 (Fuel-H2O-Air)</td>
</tr>
<tr>
<td><strong>O$_2$ Transfer Capacity/Rate</strong></td>
<td>4wt% / Fast</td>
</tr>
<tr>
<td><strong>Fuel</strong></td>
<td>Coal/Syngas</td>
</tr>
<tr>
<td><strong>H$_2$ Production Capacity</strong></td>
<td>4kW (2018, + Heat 200kW)</td>
</tr>
<tr>
<td><strong>Development Start</strong></td>
<td>2007&quot;^(1) (Ohio State University)</td>
</tr>
</tbody>
</table>

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^(1)" Denotes development in academic institutions.
Leveraging its experience as the leader in developing ammonia facilities by capacity, CARBONCO is developing the ammonia-hydrogen supply chain and its own proprietary ammonia cracking technology in collaboration with KEPCO.

**Process Overflow**

- **Synthesis, storage and transport of ammonia is a well-established industry**
- **Ammonia**
  - **Ammonia Cracking Reactor** (2NH₃ → N₂ + H₂)
  - **Heat**
  - **Heat Exchanger**
  - **Burner**
  - **Output Flue Gas**
  - **Input Air**
  - **Tall Gas (NH₄·H₂·N₂)**
  - **H₂ Buffer Tank**
  - **H₂ Product**
  - **Ammonia gas goes through pre-heating process in a heat exchanger**
  - **The exhaust gas heat from the rear end of the ammonia cracking reactor is used for evaporation and preheating of ammonia**
  - **Unreacted ammonia is used as burner fuel**

**Ammonia Cracking Technology: KEPCO**

<table>
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<tr>
<th>Specification</th>
<th>CARBONCO</th>
<th>KEPCO</th>
</tr>
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<tbody>
<tr>
<td><strong>Companies</strong></td>
<td><strong>CARBONCO</strong></td>
<td><strong>KEPCO</strong></td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td>Large-capacity expandable design</td>
<td>Small/medium capacity compact design</td>
</tr>
<tr>
<td><strong>Catalyst Technology</strong></td>
<td>Use of commercial catalyst technology/facilities</td>
<td>Use of laboratory catalyst/manufacturing methods</td>
</tr>
<tr>
<td><strong>Heat Supply</strong></td>
<td>NH₃/H₂ combustion (carbon-free)</td>
<td>NH₃/NG combustion (carbon emitted)</td>
</tr>
<tr>
<td><strong>Product</strong></td>
<td>NH₃ partial reforming hydrogen</td>
<td>High-purity hydrogen</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Gas turbine of hydrogen cofired/fired power generation</td>
<td>Hydrogen charging station (transportation, etc.)</td>
</tr>
<tr>
<td><strong>Demonstrated Scalability</strong></td>
<td>470tpd</td>
<td>2tpd</td>
</tr>
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</table>

- **✓ CARBONCO is co-developing an ammonia cracking process that yields high conversion rate >99%**
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  - Ammonia/Hydrogen

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- Project Cases Studies
  - Case 1: Coal-Fired Power Plant “CCU” Project
  - Case 2: Waste Energy Power Plant “CCU” Project
  - Case 3: Desalination Plant CCU Project
  - Case 4: Waste-to-Energy “CCU” Project
Case 1: Coal-Fired Power Plant “CCU” Project

CARBONCO proposes carbon capture and mineralization solution for coal-fired power plant. Coal-fired power stations emit over 10 billion tons of carbon dioxide each year, about one fifth of world greenhouse gas emissions. This makes these stations the single largest cause of climate change.

Project Overview

Coal-Fired Power Plant

- The coal is fed into a power plant as fuel, and its flue gas is released to atmosphere.
- Coal-fired power stations emits high concentration and volume of carbon dioxide.

Flue Gas

Coal-Fired Power Plant

CCU Plant

- Flue gas is pumped into a CCU plant and CO₂ is absorbed through capture process.
- Captured CO₂ is then transported to carbon mineralization plant.

Carbon Capture

Carbon Capture Plant

Carbon Mineralization Plant

- Through carbonization process, the CO₂ is mineralized with the byproducts (ash) from CFPP as calcium carbonates. Besides calcium carbonates, rare earth elements like scandium, praseodymium, neodymium, etc. By-products can be separated.
Case 2: Waste Energy Power Plant “CCU” Project

CARBONCO offers tailor-made decarbonization solutions. CCUS technology is a ready-to-adopt technology that can be directly applied to existing various industries to reduce greenhouse gases and create added value simultaneously. CARBONCO presents consulting services to assist clients in finding customized decarbonization solutions.

**Project Overview**

**Steel Mill**
✓ The IEA estimates that direct CO₂ emissions due to crude steel production are approximately 1.4 tons of CO₂ per ton of steel produced.

**Waste Energy Recovery Co-Generation Plant, Off-gas power plant**
✓ DL E&C provided the consultation and the solution to one of Korea’s major steel mills to develop a Waste Energy Recovery Co-generation plant (Off-gas power plant) to recycle energy 10 years ago.
✓ Waste Energy Recovery Co-generation plant runs on byproduct gases, which include gases produced by blast furnaces (BFG), Coke Oven Gas (COG), and Converter Gas (LDG) from Steel Mills.
✓ The off-gas power plant emits high concentrations and volumes of CO₂.

**Carbon Capture Plant**
✓ Flue gas from the off-gas power plant is pumped into a CCU plant and CO₂ is absorbed through the capture process.
✓ Captured CO₂ is then sold to off-takers as Liquefied CO₂ or Dry Ice.

**Process Overview**
Case 3: Desalination Plant CCU Project

CARBONCO is a strategic partner with major players in the Middle East’s Power Plants and Desalination plants, and they consistently attempt to incorporate CCU plants into their plants. The CO₂ produced by CCU plant can be steadily supplied to the post-treatment system of the desalination plant.

<table>
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<th>Project Overview</th>
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**Power Plant**
- Power and steam are produced by a power plant.
- NG is fed into a power plant as fuel, and its flue gas is released into the atmosphere.

**Carbon Capture**
- Flue gas is fed into a CCU plant.
- Captured CO₂ is converted into the liquid phase (L-CO₂) for transportation.

**CO₂ Injection to Desalination**
- The CO₂ is pumped into a post-treatment of SWRO desalination plant. The CO₂ is utilized to mineralize the desalination water to meet drinking water regulation.

*SWRO : Seawater Reverse Osmosis*
Case 4: Waste-to-Energy “CCU” Project

CARBONCO is elevating the circular economy with Waste-to-Energy (WTE) projects, diverting waste from landfills, reducing greenhouse gases from landfills, particularly methane (84 times more potent as a global warming gas than CO₂), offsetting emission from fossil fuel for electricity production and extracting profit from waste.

Project Overview

✓ In a landfill, waste is buried and bacteria break down the biogenic materials in the waste, generating methane and carbon dioxide.
✓ Landfills emit less CO₂ than the waste incineration facility, however, methane emitted by landfills is far greater and methane is far more potent than CO₂ as it traps heat more efficiently.
✓ Over a 100-year period, methane is 28-34 times as warming as CO₂ and 84 times more potent.

Process Overview

- Methane and CO₂ emission
- Fossil Fuel use for Incineration
- Unwanted Public Infrastructure (incl. landfill)

✓ Carbon capture and utilization
✓ Circular economy by recovering values from waste
✓ Steam & Power Production
✓ Clean and sustainable facility with profitable business

In a landfill, waste is buried and bacteria break down the biogenic materials in the waste, generating methane and carbon dioxide. Landfills emit less CO₂ than the waste incineration facility, however, methane emitted by landfills is far greater and methane is far more potent than CO₂ as it traps heat more efficiently. Over a 100-year period, methane is 28-34 times as warming as CO₂ and 84 times more potent.
Rapidly growing as a leading group in the world, DL is developing pioneering solutions for decarbonization business to remarkably reduce GHG emissions.

Contact us: www.carbonco.com / inquiry@carbonco.com