CEFCO GLOBAL CLEAN ENERGY, LLC

Newly Patented CEFCO Technology Offers Cost-Efficient Alternative for Capturing “Pure CO2” and Not Necessarily for CCS or EOR, but for Algae-to-Biofuel and C-T-L (Advanced Fuel)

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**CEFCO’s Solution**

- Use Ewan’s shockwave “free-jet collision scrubbing” (recognized by EPA/DOE) to capture \( \text{CO}_2 \) and all pollutants

- Cooper Process to convert \( \text{CO}_2 \) and all “captured pollutants” into recovered, segregated, valuable, and sellable End-Products

- USPTO Patent issued on November 30, 2010 under: **US 7,842,264B2**

- CEFCO Users:
  - 1) Comply with all EPA’s MACT and NESHAPs Requirements
  - 2) Benefit of selling End-Products: no longer “cost-center”
  - 3) Providing pure \( \text{CO}_2 \) gas to Users (via Capture in Bicarbonate Solid)
Providing “Pure CO₂” Gas to Makers of Advanced Fuels or Bio-Fuels

• Overcome High Cost and Energy Penalty associated with conventional Capture of CO₂

• Current Sources of Captured CO₂ contaminated by Traces of Amine or Ammonia

• Obstacles to Compression and Transmission of Liquid CO₂

• Solution: CO₂ can be Captured as Solid and Transported by Rail or Truck, and Released as “Pure” Gas
Newly-Patented Pathway — Captured “Pure CO₂” to Liquid Alcohol(s) and Fuel

The United States of America

United States Patent

Grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America, and if the invention is a process, the right to exclude others from practicing the process, in the case of the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America, or importing the invention into the United States of America, products made by that process, for the term set forth in 35 U.S.C. 154(a)(2) or (c)(1), subject to the payment of maintenance fees as provided by 35 U.S.C. 41(b).

The Director of the United States Patent and Trademark Office

Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this

United States Patent

A method for producing a fuel from carbon dioxide (CO₂) gas using a process that converts CO₂ gas to liquid alcohol(s) and fuel. The process involves the capture of pure CO₂ gas, followed by its conversion into a liquid form using a newly-patented pathway. The resulting liquid alcohol(s) and fuel can be used as an alternative to fossil fuels, reducing the emission of greenhouse gases and promoting sustainable energy solutions.

The process involves the following steps:

1. Capture CO₂ gas:
   - Pure CO₂ gas is captured from industrial processes or directly from the atmosphere.

2. Conversion to Liquid Form:
   - The CO₂ gas is converted into a liquid alcohol(s) and fuel through a newly-patented pathway.

3. Production of Alcohol(s) and Fuel:
   - The resulting liquid alcohol(s) and fuel can be used as an alternative to fossil fuels.

This invention is protected by the patent described above and is not subject to any other restrictions. The patent holder has the exclusive right to practice this invention or authorize others to do so.

Inventors:

The inventors of this patent are currently working on further refinements and applications of this technology to enhance its efficiency and scalability. Further details can be obtained by contacting the patent holder or the United States Patent and Trademark Office.

CEFCO

CEFCO (Clean Energy Fuel Corporation) is a leader in the production and distribution of renewable energy products. CEFCO's mission is to provide alternative fuels and energy solutions that are environmentally friendly and sustainable. CEFCO is committed to reducing the carbon footprint and promoting a cleaner future.

For more information about CEFCO and its products, please visit their website at www.cefco.com.
Many processes need to optimize Enthalpy of each reaction, and to minimize input of Energy, Pressure and Catalyst.
Background: Reforming Processes

Natural Gas or Naphtha

Steam Reforming or Partial Oxidation

H₂

Ammonia Synthesis
Hydrogenation
Fuel Cell Power
FT Synthesis of Liquid Fuels
Methanol Synthesis

Biomass or Coal

CO, CO₂ + H₂ (syngas)
G-T-L Processes: Requiring Pure CO$_2$
Algae + CO$_2$ : Alternative Bio-Diesel

Current G-T-L Steam or Dry Reforming Processes to Form Fuel

- Natural Gas
- "Pure" CO$_2$
- Steam
- Helper Steam
- Oxygen

Current Steam or Dry Reforming

- Syngas (CO, CO$_2$, H$_2$)

Fischer Tropsch

- Long-chained hydrocarbons

Cracking & Distillation

- GTL Products (Fuels, e.g., Diesel), Naphtha, Paraffins, etc.

Alternative Algae to Bio-Fuel Processes

- Algae Source
- "Pure" CO$_2$
- Sunlight
- Warmth

Algae Hydroponics

- Output of Oily Product for Bio-Fuel

Processing for Long-Chained Hydrocarbon

- Bio-Fuel Products (e.g., Diesel, etc.)

Potassium-Fertilizers (Nitrate)
Aero-Physics Science
Shockwave Reaction Mechanism

Fig. 4A: Methanol 'A' Production

Fig. 4B: Methanol 'B' Production
Comparison of Parasitic Load or Energy Penalty

Supersonic “Free Jet Collision” Shockwave Effect (Intense Pressure and Energy)

Subsonic “Free Jet” Effect Ewan’s Subatmospheric Reaction Zone (Adiabatic Conditions)

Aerodynamic Recovery of $\Delta P$ and $\Delta T$

Conversion to End-State with Refrigeration/Cooling

Mechanical Switch Over

$\Delta$ Pressure

$\Delta$ Temperature

X,000°

100°

Ambient

1sec 2secs

minutes

extended minutes
Seeing Shockwaves Being Formed

Image: Schlieren Photography – multiple shockwaves generated by shuttle craft at much higher Mach speeds

Image: Airplane beginning to cross sound barrier at Mach 1.0, showing first shockwave
Free-Jet Reaction Zone

Image: Schlieren Photography of Free-Jet Collision inside CEFCO’s reaction chamber causing an induced “subatmospheric reaction zone” with extreme adiabatic conditions
Shockwave-Induced Intimate Mixing

Image: Schlieren Photography showing shockwave-induced intimate inter-mixing and re-combination of two gas-phase molecules.
CEFCO’s Unique Reaction Mechanism

• All flue gas must pass downward through Shockwaves ➔ “no escape” from “free-jet collision” and capture effect

• Pollutants are first captured using Physics then converted into valuable end-products by using Chemistry
Application of Hess’s Law

- All molecules in flue gas are affected by shockwave = no escape
- Hess’s Law: energy or enthalpy change (\( \Delta H \) values) for any chemical or physical process is independent of the pathway or number of steps required to complete the process; only the initial and final states being important
- Reaction-intermediates are transitional and will rapidly reform or recombine into the end-product
- Final reaction equation “gets netted out” at end-product state in exothermic reaction and results in stable end-product at much lower range of temperatures
- If net enthalpy change is negative (\( \Delta H_{\text{net}} < 0 \)), reaction will be exothermic and is more likely to be “spontaneous” (which means in “a split-second”)
- Exothermic reaction provides fresh addition of heat being released into flue gas phase and assists in energy and pressure recovery = lower “parasitic loss”
The CEFCO Process uses a comprehensive re-circulating and re-generating system that optimizes the conservation of water, energy, and all required inputs.
CRS (CO$_2$) Module

• Reactions inside the Aerodynamic System (verification of Hess’s Law):
  • CO$_2$ + KOH (reagent) $\rightarrow$ KHCO$_3$ (Carbon Capture)
  • CO$_2$ + K$_2$CO$_3$ (reagent) + H$_2$O $\rightarrow$ 2 KHCO$_3$ (Carbon Capture)

• Transient Reactions (Hess’s Law):
  • CO$_2$ + H$_2$O $\rightarrow$ H$_2$CO$_3$
  • KOH (reagent) + H$_2$CO$_3$ $\rightarrow$ KHCO$_3$ + H$_2$O (Carbon Capture)

• Conventional Reactions after leaving the Aerodynamic Coalescer:
  • Decarbonation = Liberation of Carbon Dioxide
  • Heat + 2 KHCO$_3$ $\rightarrow$ K$_2$CO$_3$ (regenerated) + CO$_2$ (liberated gas) + H$_2$O

• Note: K$_2$CO$_3$ re-generation process liberates CO$_2$ as gas and produces supply of recovered water for many subsequent uses
CEFCO’s Reaction Mechanism

• Supersonic Shockwave itself = Input of Energy & Pressure + acts as needed Catalyst
• Shockwave “Free-Jet Collision” (DOE’s and EPA’s description in numerous reports) = Molecular Surface Chemistry
• Shockwave energizes Targets to react in shortest time + causes Adiabatic Condition that enables Endothermic-then-Exothermic Reactions
• Shockwave shatters Reagent Solution injected into finest micro-droplets = enhancing molecular surface contact areas
• Intimate and Rapid Intermixing & Reaction
• Reaction Kinetics predominates over other conventional thermodynamic issues
• Hess’s Law explains the rapid conversion into End-Products
Pilot Plant at Peerless

- in Wichita Falls, TX
- 3 tons/hr of Flue Gas
Successful Capture of Potassium Fertilizer and CO$_2$
Three Layers of End-Products

Liquid Potassium Sulfite Fertilizer

Potassium Sulfate Fertilizer Crystals

Potassium Bicarbonate Crystals (CO₂ Capture)
CO$_2$ Captured and Converted into Easily Transportable Solids

Potassium Bicarbonate = KHCO$_3$ (Solid)

Sodium Bicarbonate = NaHCO$_3$ (Solid)

Heat + 2 KHCO$_3$ [ or 2 NaHCO$_3$] $\rightarrow$ K$_2$CO$_3$ (regenerated) [ or Na$_2$CO$_3$] + CO$_2$ (liberated gas) + H$_2$O

Note: K$_2$CO$_3$ [ or Na$_2$CO$_3$] re-generation process liberates CO$_2$ as a pure food-grade gas and produces supply of recovered water for many subsequent uses. The K$_2$CO$_3$ [ or Na$_2$CO$_3$] can be returned to the CEFCO Process to be re-used as the Reagent in the CRS
Summary

• Game-changing “transformative reaction mechanism technology” = perfect marriage between Aerospace Physics and Chemistry

• Environmental responsibility = “Pure” CO₂ can be captured in Bicarbonate Solid
  • Much Cheaper and Safer to ship by Rail or Truck
  • Avoid high cost of Compression and Pipeline Transmission of amine-contaminated CO₂

• Reliable and affordable energy:
  • Aerospace science reaction mechanism as low-cost substitute for traditional thermodynamics and catalysts
  • Pollution Control = “profit-generation” business; ≠ “cost-center”

• Proposing Air-Gas Separation to Harvest the Remaining N₂, O₂ and Noble Gases in the exiting Flue Gas Stream
Questions & Answers

Thank you very much for your attention.

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