Carbon Recycling with the Electroreduction of Carbon Dioxide (ERC)

The Need

Carbon dioxide is increasingly notorious as a cause of global warming. In fact, the EPA estimates that US industry produces approximately 147 terragrams of CO2 equivalent, approximately 30% of which comes from the production of iron and steel. As Illustrated below, CO2 accounts for 84.8% of all emissions, with Electricity Generation having the greatest impact of all economic sub-sectors. (Environmental Protection Agency, 2006

♦ ♦ ♦

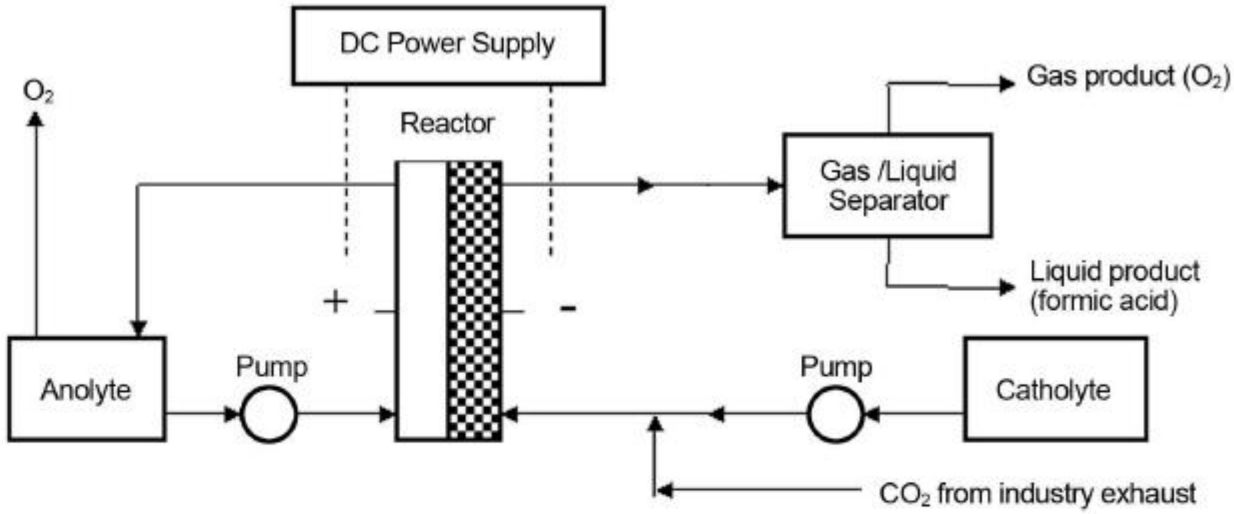
Subsequently, public and regulatory scrutiny has become a major burden to large stationary industrial producers. However, other than energy conservation, Carbon Capture and Storage (CCS), the process of separating CO2 from emission sources and transporting it to a storage location for long-term (indefinite) isolation, is the only potentially viable option for CO2 reduction today. Carbon Sequestration, the process of permanently storing CO2 underground, has garnered the most significant attention to date, with corporations and governments committing $ Billions USD in large sequestration pilot projects and research. Nonetheless, this technology still faces significant challenges, as it is far from being cost effective. In addition, sequestration has raised serious environmental concern, legal and regulatory issues due to the unknown ramifications of permanently storing CO2 underground.

The amount of CO2 emitted annually from industry, fossil fuel combustion and utilities, coupled with the aforementioned lack of viable mitigation technology, presents a giant window of opportunity for entrants into the CCS market.

Technology

In November 2007, Mantra acquired the 100% outright ownership of a chemical processing technology developed by the University of British Columbia's Clean Energy Research Center, entitled the Electroreduction of Carbon Dioxide (ERC). Powered by electricity, ERC combines captured carbon dioxide with water to produce high value materials that are conventionally obtained from the thermochemical processing of fossil fuels, including: formic acid, formate salts, oxalic acid, and methanol.

Rather than worry about the impacts and properties of CO2, Mantra harnesses its useful properties and transforms the gas into several useful and valuable by-products.

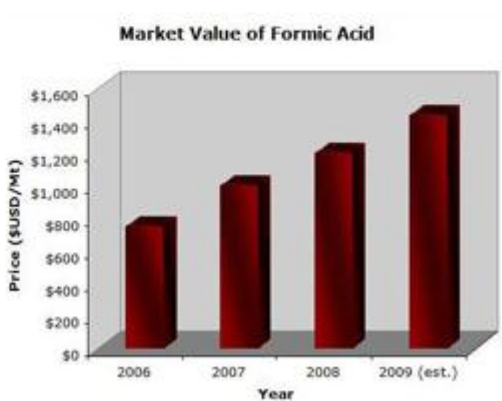


Advantages of ERC technology

MVTG management asserts the following potential advantages relative to alternative methods of CO2 capture and conversion:

- Process is driven by electric energy that can be taken from an electric power grid supplied by hydro, wind, solar, tidal or nuclear energy (all renewable).
- Medium reaction rate allows for commercial viable CO_2 processing times
- Medium CO_2 space velocity gives the ability to treat comparatively large volumes of CO_2.
- High product selectivity for formate and formic acid (up to 90%)
- Low operating temperature (20° to 80° Celsius) and pressure (below 1 MPa or magnitude of pressure)
- Hydrogen is not required as a feed reactant, but is already present in water used in the process
- ERC by-products represent useful, and financially profitable sources of income
- ERC pilot projects can be executed on any scale, whereas sequestration can only be performed on a very large scale, leading to exorbitant research and development expenditures

Markets



Mantra's objective is to make electrochemical reduction of carbon dioxide not only cost effective but profitable for emitters for whom CO2 management is either mandated or desirable. Therefore, the primary market for ERC technology will be the **major sources of stationary CO2 production: industry, fossil fuel combustion,**

and utilities. The International market for carbon dioxide management is currently in the Billions USD and carbon emission credits are traded at values up to $40 USD per ton of CO2. Iron and Steel Production in the US alone accounted for 45.2 Terragrams of CO2 equivalent in 2005, representing approximately 30% of overall CO2 emissions from industry. (Environmental Protection Agency, 2006)

Download the Opportunities for Formic Acid FAQ Sheet.

Upon successful entry into the CO2 market, a powerful and perhaps even more profitable market will develop for its useful by-products. Sodium Formate and Formic Acid, two of the main by-products of ERC, currently have an average market value of $1,200/ton, with more than 600,000 tons of formic acid produced annually (Li, 2006). Their applications are diverse, including feedstock preservatives, de-icing solutions, cleaning solutions and baking soda to name a few. The market for formic acid has experienced continual growth and demand over the past several years, mainly attributed to the following: European and developing country demand for formic acid in silage, rising raw materials, energy and logistics costs; and animal feed preservative and Asian demand for formic acid in the leather, rubber, food and pharmaceutical industries. The average market price of formic acid is expected to increase by as much as 20% in 2009. (Dunia Frontier Consultants, 2008)

However, if the ERC process reaches market acceptance as a way for industry to deal with exhaust gas from power production, it will likely lead to supply of formic acid in excess of market demand. Fortunately, Mantra has identified several future applications for formic acid, leading to a prolific expansion in current market demand, including steel pickling, fuel cell development and as a fuel additive.

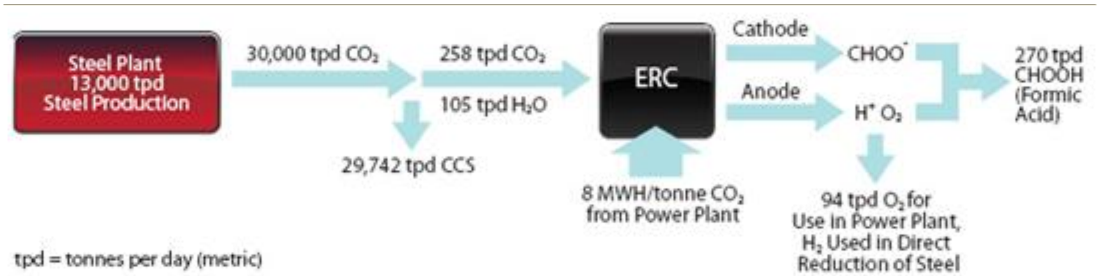
♦ ♦ ♦

STEEL PICKLING

Steel Pickling is part of the finishing process in the production of certain steel products in which oxide and scale are removed from the surface of strip steel, steel wire, and other forms of steel, by dissolution in acid. A solution of either Hydrochloric Acid (HCl) or Sulfuric Acid is generally used to treat carbon steel products, while a combination of Hydrofluoric and Nitric Acids is often used for stainless steel.

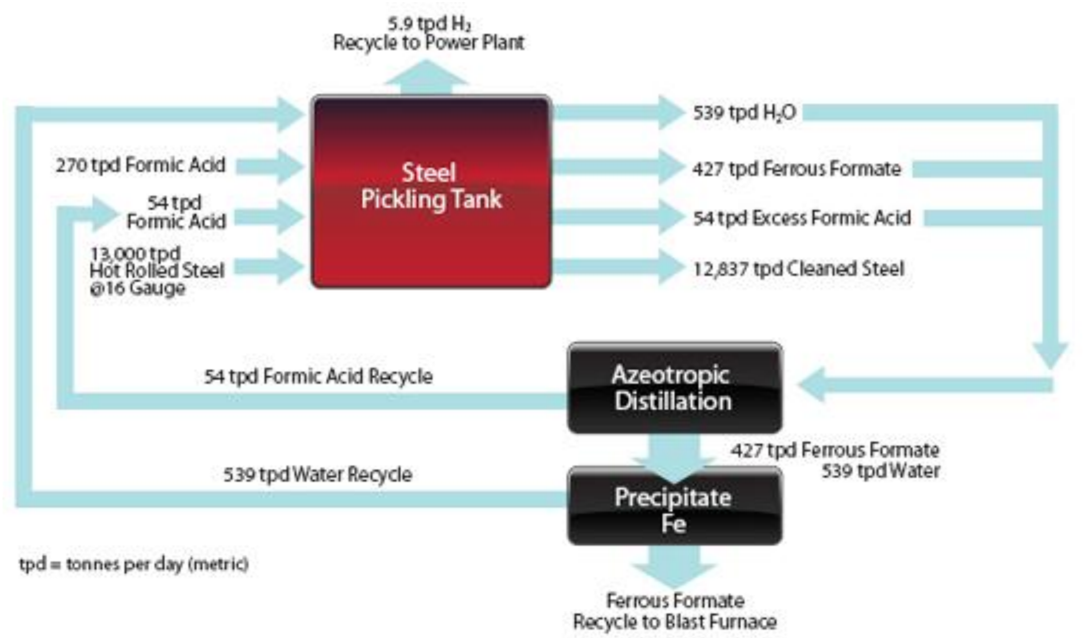
As an organic acid, Formic Acid would be a very attractive replacement for Hydrochloric Acid (HCI) in the steel pickling process. Formic Acid has many advantages over HCI under this application, including: less iron would be lost from the steel surface, the final surface quality would be improved, corrosion inhibitors and neutralizing rinse process would be eliminated. In addition, Formic Acid is both bio-degradable and reusable and process water could be recycled more easily. The following diagrams depict the production and usage of Formic Acid in a 13,000 tpd steel plant.

Formic Acid Production in a Steel Plant



The following shows the integration of Mantra?s ERC system into a steel mill making 13,000 tpd of 16 gauge rolled steel; ERC is designed to take the CO2 from the steel plant and convert it into Formic Acid which is then used to replace the use of Hydrochloric Acid in pickling the hot-rolled steel. In the manufacturing process, iron ore is converted into steel which is poured into billets; these are later reheated and rolled into strip steel; as they are being rolled oxides form which must be removed to provide a clean surface. The finished steel strip goes on to make refrigerators, car panels or other steel products.

Formic Acid Use in a Steel Plant

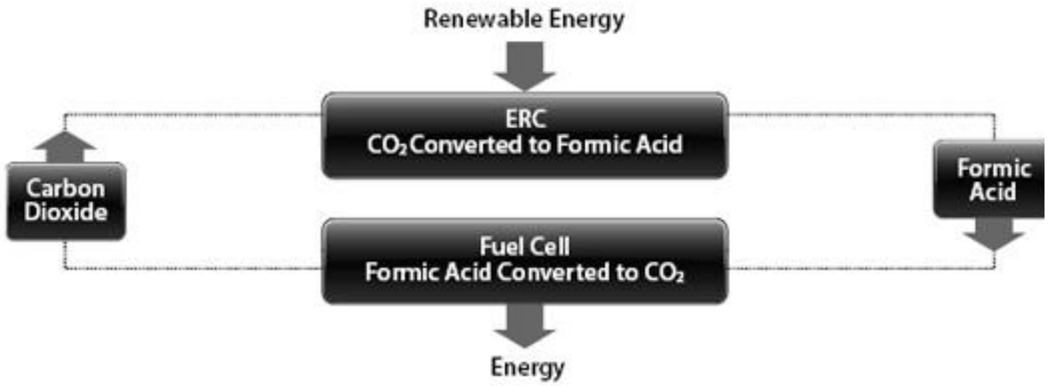


Approximately ¼ of the HCI produced in the U.S. is used for pickling steel (American Chemistry, 2003), consuming an estimated 5Mt/year.

♦ ♦ ♦

FUEL CELLS

Another potentially lucrative market for formic acid is in **Fuel Cells**. In fuel cells, liquid fuels are indirectly combined with oxygen to form carbon dioxide and water, while generating electricity- a process known as electro-oxidation. The complimentary nature of ERC and electro-oxidation makes it possible to use ERC in a regenerative fuel cell cycle, where CO2 is converted into a fuel that is consumed in a fuel cell to regenerate CO2.



The development of direct formic acid fuel cells (DFAFCs) is likely to be a significant commercially valuable use of formic acid. DFAFCs are gaining popularity over hydrogen and methanol based fuel cells because of their ease of refueling, efficiency, and safety. DFAFCs are currently being tested by major producers of portable electronics in phones, laptops and computers. With continued development, there is potential for DFAFCs to challenge traditional batteries as power sources for mobile electronic devices with large scale applications expected to follow.

♦ ♦ ♦

FUEL ADDITIVE

In addition to the production of formic acid, the ERC process can be adapted to produce ammonium formate- a potential fuel additive currently being tested in Europe and Japan. This chemical compound shows great promise in reducing NOx emissions when added to diesel fuel- potentially representing yet another secondary market for the electroreduction of carbon dioxide.

Partnerships

Given the magnitude of the ERC project, both government and corporate partnerships will play a pivotal role in further development of the ERC technology.

Government Programs and Grant Relations

A Grant Research Report, completed in February 2009, identified 43 funding programs that fit strategically with the company?s current R&D efforts. Mantra has already began applying for those grants as recommended in the report, and if successful, Mantra could recover anywhere from 70% to 100% of future development costs. The Company expects to receive approval from its first Grant application by the end of March, 2009.

The objective of this first Grant Program is to establish the technical basis for electro-reduction of carbon dioxide to formate via continuous electrochemical reactor. The main milestones to be achieved are: i) to develop longevity of catalyst materials for anode and cathode used in the electrochemical reactor, ii) to develop an in-situ catalyst regeneration method for the cathode catalyst material, and iii) to resolve formate crossover and prolong the lifetime of the employed membrane.

Corporate Partnerships

Mantra has been in contact with several key players within its identified target markets, including: environmental risk management, steel production and pickling, chemical production (formic acid), utilities and fossil fuel production.

Mantra is now in the process of finalizing Partnership Agreements with a host of international corporations, and while yet to be finalized, the aforementioned agreements should lead to increased capital resources to expedite development and optimization of the commercial scale ERC reactor. Mantra will also benefit from international exposure in areas including Asia, Western Europe and Australia, and ultimate entry into applicable markets. The Company is looking to finalizing these first set of agreements by May 2009.

Capitalizing on Electroreduction of Carbon Dioxide

The estimated electrical cost of producing formate from CO2 is 8MWhr per ton. This is approximately $480 of electricity per ton of product at $0.06 per KWhr. The formate market price is approximately $1,200 per ton. Factors such as carbon credits, savings in shipping for on-site production and use, and savings with respect to using formic acid (for improved process performance) over other inorganic acids improves economics even further.

The following is a list of potential revenue sources of income to Mantra from ERC:

Revenue Source	Estimated Start Date
Demonstration projects	Q3 2009
Licenses for various applications	Q3 2009
Off-take (licenses for sale of product)	Q2 2010
Royalties	Q2 2010
Step-out Patents (possibly with third parties)	2010
Ultimate sale of the technology	2013 (or sooner)

Mantra has forecasted a ROI for the user of ERC of between 5% and 20%, however, this estimate will become more accurate with additional lab testing.

In addition, Mantra stands to benefit from significant revenue generation through the sale of ERC by-products- formic acid being the main contributor. As ERC succeeds and produces formic acid in volume, numerous applications for formic acid are expected to develop, rapidly expanding upon its current market. The following is a broad projection of potential worldwide markets for Formic Acid:

Application	Potential Market Size (Annual)
Existing demand	$0.75 billion
Hot Rolled Steel pickling	$5 Billion
Pulp Processing	$4 to $5 Billion
Total Worldwide	$10 Billion

Management estimates that by leveraging upon government support and corporate partnerships, ERC could develop and prosper in these markets, taking 50% of total market share for formic acid within 5 years ($5 Billion USD). While the increased availability and production of formic acid may erode its current market value, simultaneous technological improvements and volume price breaks are expected to ensure ERC?s success within the marketplace.

Opportunities related to Formic Acid

Formic acid is of interest to Mantra because of its ERC technology, electro reduction of CO2, an alternative to CCS, carbon capture and storage. ERC is very different from CCS, it is a form of carbon recycling. It has many advantages (see the Mantra brochure), one of which is the production of a valuable end product, formic acid.