

ARCTECH, Inc. is a diversified company that provides technologies, services and products to meet growing needs of clean energy and for preserving the environment. Formed as a spin-off company from the Environmental Science and Technology division of the Atlantic Research Corporation, the ARCTECH group through 25 years of experience in energy, energetics, environment and agriculture, has created out side the box solutions in these interrelated market sectors. The entrepreneurial scientists and engineers at ARCTECH have pioneered the use of vast resources of coal and coal-derived humic acid products such as actosol® fertilizer; HUMASORB®, a multipurpose contaminant adsorber; ACTODEMIL®, for cost effective disposal of munitions; and an overall encompassing MicGAS™ technology described herein for production of clean energy while eliminating the build up of greenhouse CO<sub>2</sub> emissions. For additional information about our products and applications, please visit our web site: [www.arctech.com](http://www.arctech.com)

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*Preserving tomorrow's world... today*

# Balancing The Earth

## Pre-Combustion Carbon Sequestration With MicGAS™ Coal Biotechnology



### An Unified Solution For:

- Economical Clean Energy
- Cleaner Water & Environment
- Safer Food Production
- Recycling Military & Industrial Wastes
- Reducing Greenhouse Gas Emissions
- Energy Security with Domestic Coal Resources

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*Preserving tomorrow's world... today*

## Pre-Combustion Carbon Sequestration With MicGAS™ COAL BIOTECHNOLOGY

In 1995 Vice President Al Gore wrote a book entitled “Earth in the Balance”, highlighting the adverse global changes which have occurred since the industrial revolution and their impact on our very existence. He pointed out the adverse consequences of the emissions of greenhouse gases, the continued loss of top soil, and the pollution of our environment. He stressed an urgent need for global action to balance our human needs with our planet’s ecology and today he has been recognized for his efforts by being awarded *2007 Nobel Peace Prize*. Many experts and the general public are seeking drastic solutions, but are concerned with costs to the worldwide economies, especially today when there is a critical need to meet the basic requirements of rapidly increasing population and worldwide economic growth underway.

The MicGAS™ biotechnology offers an economic and practical approach of utilizing our vast resources of coal to reverse the adverse global impacts. Coal, to date has been primarily used as fuel or carbon. The MicGAS™ biotechnology converts coal into clean fuel gas (methane or natural gas) and organic humic matter. The primary strategy of the technology is to capitalize on the plant origin of coals to create highly useful humic products, while bio-converting coal into methane gas for production of affordable, clean energy. The humic matter derived from coal is same as the natural humic component of organic soil matter, and is useful for replenishing soils for increased food production, recycling wastes, and cost effectively cleaning our contaminated waters and soils. A broad based implementation of this integrated technology solution will result in pre-combustion sequestration of carbon in useful humic products, while enhancing worldwide economies.

The industrial revolution, which started about two centuries ago, has been fueled with ever increasing use of fossil fuels, most notably coal. This has resulted into unprecedented economic growth worldwide, and has changed forever our relationship with our planet earth. One of the major impacts now recognized is global warming resulting from build up of greenhouse gases, especially CO<sub>2</sub> due to burning of fossil fuels. The greenhouse effect, by which a small amount of solar heat is retained near the surface of our planet, is critical to maintain the fragile life and ecology. However, unacceptable levels of accumulation of these gases in our atmosphere is now believed to cause gradual heating of the planet. This effect has the potential to cause drastic adverse ecological imbalances for inhabitants throughout the world.

In December of 1997, the United Nations sponsored a Global Climate Convention held in Kyoto, Japan. At this convention, 160 Nations gathered for landmark negotiations and negotiated a treaty to reduce worldwide gas emissions. The objective of the treaty is to reduce emissions levels to those below 1990 levels, between 2008 and 2012. For example, the U.S. is required to reduce 7% of CO<sub>2</sub> emissions to below the 4.8 billion tons emitted in 1990, thereafter maintaining a yearly level of emissions of 4.5 billion tons. Considering the continuing increase in emissions, the required net reduction today exceed 40%. The energy experts agree with the overall reduction levels, but are concerned with time-line and predict that this requirement will drive up the cost of electricity production. The climate experts assert that significant rapid reductions are critical to reverse the ecological impacts.

Today, the U.S. is home to only 5% of the world’s population but emits 25% of its greenhouse gases. Thus, U.S. industries and government must respond to this challenge by reducing the emissions of greenhouse gases, while sustaining the market-based economic growth needed for today’s rapidly changing, competitive world economies. The present administration is concerned about curbing CO<sub>2</sub> emissions from power plants particularly during a burgeoning energy crisis. The administration leadership is seeking new ways to deal with the problem.

A number of varied strategies for CO<sub>2</sub> reduction being considered include: improved fuel and energy efficiency, forestation, and reforestation of lands to increase CO<sub>2</sub> adsorption; capture CO<sub>2</sub> for reuse and disposal in land and ocean reservoirs; and switching to less CO<sub>2</sub> producing fuels. Recently, there has been a big boost for biofuels especially ethanol in response to high oil prices and need for replacement of toxic additives such as MTBE. However, substitution of ethanol for petroleum fuels does not address the needed for CO<sub>2</sub> reduction requirements. Already a significant progress is being made in improving fuel and energy efficiency, but most experts believe that even though it is beneficial it is not sufficient to address the problem.



**Over 1 Billion Tons Of Coal Is Mined in 38 States  
Throughout The United States.**

The primary benefit demonstrated in these applications is that yields of crops and plants increase 10-100%. This results in a net value gain of about 4 to 20 times of costs to a farmer.

Several projects are underway at ARCTECH to implement applications of humic acid to meet our challenging environmental needs. These projects include the successful development of a novel adsorbent termed HUMASORB-CS® (a water insoluble polymer). This novel adsorbent has been shown to remove both inorganic and organic contaminants in a single step from water at a cost savings of as much as 50% than conventional approaches. HUMASORB-CS® is being evaluated for emplacement as a subsurface barrier at large groundwater contaminated sites, thus presenting a permanent low-cost solution. Two patents on this highly versatile adsorbent have been awarded by the U.S. Patent Office (#5,906,960 and #6,143,692).



**HUMASORB® Treatment Unit for  
Removal of Toxic Metals from Wastewaters  
at U.S. Army-Johnston Island**

ARCTECH is also successfully demonstrating applications of its humic acid-based ACTODEMIL® technology for recycling of nitrogen-containing energetics from conventional munitions into usable fertilizers.

This fertilizer product has met all regulatory requirements, and was approved for use by the Nevada Division of Environmental Protection for land application.

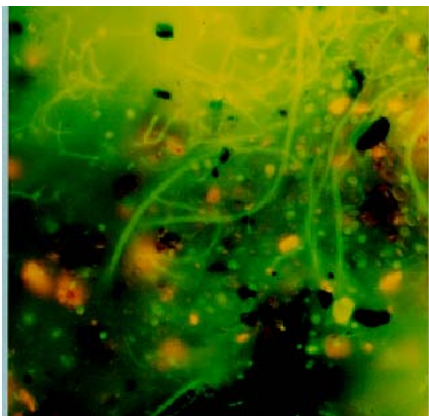


**Actodemil® Unit for Safe Destruction and Recycling  
of Explosives into Fertilizer**

The U.S. Patent office awarded a patent to ARCTECH on July 25, 1996 under Patent Number 5,538,530, entitled, “*Method for Safely Disposing of Propellant and Explosive Materials and for Preparing Fertilizer Compositions*”. The U.S. Army selected ARCTECH’s ACTODEMIL® technology for further evaluation for the safe disposal of chemical munitions, which contain both energetics and chemical agents. These applications truly incorporate the philosophy of “swords to plow shares”.

ARCTECH’s vision and strategy of MicGAS™ technology clearly provide a means of utilizing coal for cleaner power generation and enhancing the planet’s ecology, while creating economic growth. This strategy would also create a path forward, most probable in this century, towards hydrogen based energy systems.

*A fully integrated approach of using coal to produce cost effective energy, enhance agriculture and protect the environment shall mitigate greenhouse effects, and at the same time initiate the start of the second industrial revolution...just as steam production from coal combustion helped to propel the first industrial revolution, two centuries ago.*



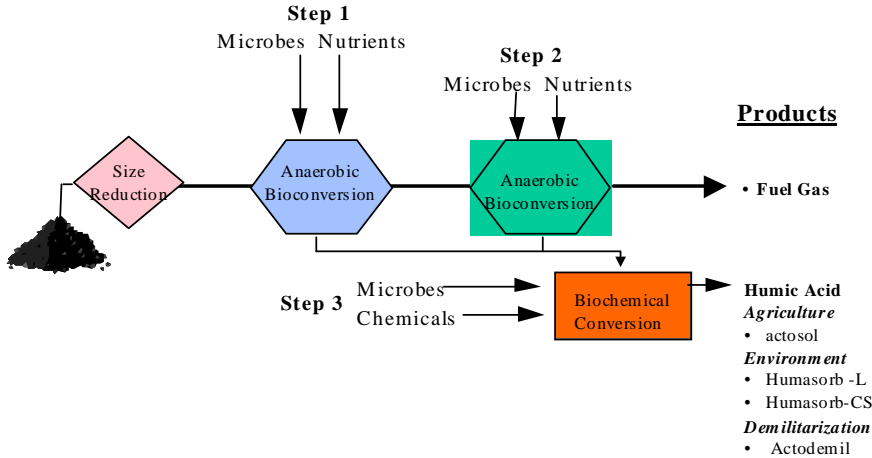
**Microorganisms Isolated From The Termites Anaerobically Converting Coal**

*The MicGAS™ process has been patented by ARCTECH, as U.S. Patents #5,670,345, and #5,854,032. “Biological Production of Humic Acid and Clean Fuels from Coal”.*

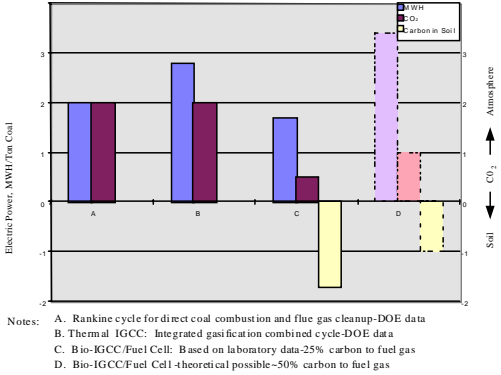
ARCTECH has developed this technology by adapting microorganisms (derived from wood eating and humus eating termites) to coal in presence of other appropriate nutrient components. The process conditions have been optimized, so that the technology can be applied in typical sewer treatment bioreactors. The technology can also be adapted for applications in insitu coal seams.

The bioconversion is accomplished in three major steps. In the first step, the hydrolytic and fermentation process, microbes convert the coal into volatile organic liquids (primarily acetate and CO<sub>2</sub>). In the second step, the liquid from the first step, along with the gases produced, are contacted with methanogenic (“methane producing”) microbes which hydrogenate the acetate and CO<sub>2</sub> to methane. The methane produced is separated and the unconverted residual coal then, in the third step, undergoes a biochemical conversion. In this step, the coal residue is converted into humic acid for formulating into agriculture and environmental products..

### MicGAS™ COAL BIOCONVERSION TECHNOLOGY SCHEMATIC



In its simpler version, the MicGAS™ technology converts carbon in coal into two primary components. One is hydrogen rich clean fuel gas and the second is carbon rich humic acid products. The use of clean fuel gas in higher efficiency advance power generation systems such as gas turbines and fuel cells, will keep the costs of electricity production low, while reducing the emission of CO<sub>2</sub> emissions for every unit of power production than today’s approach. The use of humic acid for enhanced vegetation will further remove carbon dioxide from the atmosphere through natural processes. This coal utilization concept is similar to that used in an oil refinery. A barrel of crude oil as a result of cracking and refining provides a multitude of products that are valued several times higher than the price of crude itself. The higher value obtained from the sale of these by-products (petrochemicals) enables the oil industry to sell #6 oil at almost the same or below the price of crude coming into the refinery. Implementation of the MicGAS™ technology, while creating a solution to global warming, will also result in creating a ten fold increase in value from a ton of coal over today’s approach of coal utilization. Though the strategy of MicGAS™ follows the oil refinery multiple product scenarios, it centers around products based on humic acid products unique to coal. These products will serve large agricultural and environmental market sectors, and thus will not compete with traditional petrochemical products.



A widespread application of humic acid products is therefore needed to mitigate CO<sub>2</sub> emissions and at the same time create high value from our vast coal resources. Thus, ARCTECH in the past ten years, has developed several innovative applications of humic acid for both agriculture and environmental markets.

Humic acid is a black to brown, highly functionalized, carbon rich macro-molecule. The structural makeup and properties of this chemical have been the subject of extensive research studies at various universities and research institutions throughout the world. Recently, the pre-eminent researchers at three universities (Temple and Northeastern in the U.S. and Birmingham in the U.K.) have announced a breakthrough understanding of the humic acid molecule. They have evaluated humic acid samples from a wide variety of sources and locations in both North America and Europe, and have found these materials to be remarkable in not only uniform chemical composition but also similar attributes in terms of ability to capture metal ions. These researchers have put forward a new model structure (TNB Model) of this uniform polymer consisting of repeated units called building blocks. These building blocks are joined together through a peptide-like linkage. Joining four building blocks results into a helical structure. This helix has a central cavity for water, metal and solute binding. The water filled helical model is consistent with properties of many different humic acids extracted from many different places.

As a water retainer, metal binder, and absorbent, humic acid is essential to maintenance of fertile soils. Humic acid’s water retention property gives the earth a thermal buffer capacity that prevents catastrophic climates. The versatile characteristic properties of humic acid include: a high cation exchange capacity, the ability to chelate metals, the ability to adsorb organics, a high water holding capacity, an ease of precipitation at low pH or in the presence of coagulants, and an ease of combustion due to its organic nature. These versatile properties are useful for agricultural and environmental purposes.



The above described diverse properties of humic acid make it extremely useful material for increasing yields and nutrition of our food, while enabling safe agriculture practices. The environmental applications include cost effective removal of both metal and organic toxins from contaminated waters, recycling of industrial wastes, and even the safe disposition of the most dangerous chemical agents and explosive chemicals devised for the military warfare.

The MicGAS™ technology provides an approach of pre-combustion sequestration of coal carbon as useful humic acid products for meeting our critical human needs of safe food and clean environmental. This offers the potential of completely mitigating the emissions of greenhouse CO<sub>2</sub> gas by both direct and indirect approaches. The direct reduction shall result from the use of coal-derived methane gas in lower CO<sub>2</sub> producing power plants. The indirect reductions shall be realized through enhanced CO<sub>2</sub> capture by increasing vegetative growth in humic matter enriched soils.

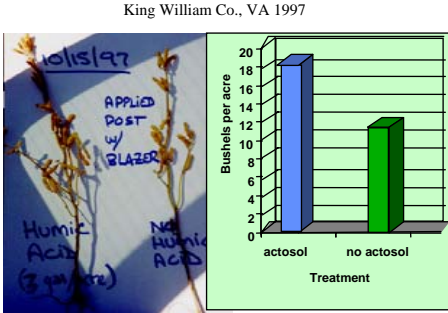
Recognizing the potential for MicGAS™ technology, ARCTECH has built a pilot-production facility to produce humic acid from inherently-humic rich lignite. At this facility in Sterling, Virginia, ARCTECH produces humic acid and formulates it into commercial actosol® fertilizer products. ARCTECH is also conducting several developmental projects focusing on environmental cleanup of the U.S. DOE Weapons Complex, and the safe disposal of DOD munitions.



Before actosol® was sprayed on the sand dunes. After actosol® was sprayed on the sand dunes.

Humic Acid Fertilizer Enables Growth of Vegetation, Even In Beach Sand (Ocean City, Maryland).

actosol® fertilizer products are being successfully marketed worldwide. In the U.S. actosol® is widely used for golf course maintenance, landscaping, erosion control, and for agricultural crops such as corn, wheat, and soybean. actosol® is also being successfully marketed in the Middle East to enhance growth of alfalfa, palm trees, and other crops grown both in greenhouses in the harsh desert climate. On the prosperous island of Mauritius, in the Indian Ocean, actosol® is being used to increase yields of sugar cane, while in South Korea, actosol® has been introduced into the marketplace for golf course and greenhouse applications. actosol® is presently being tested for distribution in the Chinese market.



Increase In Soybean Yield Using actosol®

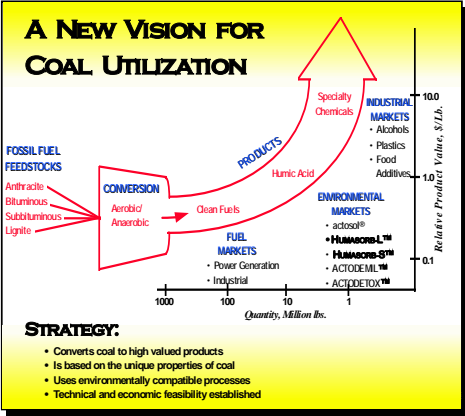
Coal, being the least efficient fuel in terms of Btu to electric energy, and highest CO<sub>2</sub> producing fuel compared to natural gas and petroleum fuels, faces a serious challenge and may become obsolete. Coal is the most abundant and least costly fossil fuel available today. With increasing economic growth and world population, increased use of all fossil fuels is critical well in this new century and beyond. Sustainability of abundant coal resources as a viable fuel in the strategy is not only needed to produce low cost energy, but also to sustain the enormous economic infrastructure which millions of Americans depend upon for employment.

The power industry depends upon coal for more than one-third of its fuel needs, and constitutes the largest market for coal. The conventional method of generating electricity with coal involves spraying finely pulverized coal, along with hot air, into a furnace chamber lined with water-filled coils. Coal burning inside the chamber converts the water in the tubes to steam, which is then used to rotate a turbine-power generator. This process, devised more than a century ago, is termed the “Rankine Cycle”. The use of emissions controls has recently been mandated to prevent pollutants such as sulfur dioxide and fly ash from being discharged into the atmosphere. Alternatives to this approach have also been explored. However, successes in the development of synthetic fuels and coal gasification have been limited due to the high costs involved with these conversion technologies.

Today, high oil prices and increasing dependence on vulnerable supply sources of oil, coal is again being considered for production of synthetic fuels utilizing the WWII technologies. These technologies based on thermal conversion have been in use in South Africa for many years, although can compete with today’s high oil prices, but result in increase in carbon dioxide emissions compare to fuel production oil and natural gas. An integration of MicGAS Coal Biotechnology with proven methane reforming and Fisher-Tropsch results in not only producing liquid fuels at prices, which will compete with \$5-10 per barrel oil, but will also lower carbon losses during bioconversion but more importantly create an economical approach of removing CO<sub>2</sub> from atmosphere through increased biomass, which will result from use of humic acid as shown below:

In one innovative stroke, this technology would create a practical approach of mitigating effects of CO<sub>2</sub> greenhouse gas while enhancing economic growth of the United States and worldwide economies. **It would:**

- **Virtually eliminate further buildup** of CO<sub>2</sub> directly through the use of lower CO<sub>2</sub> producing fuel gas, and indirectly as carbon sink through the pre-combustion sequestration of useful humic acid in soil for enhanced vegetation;
- **Enhance economic growth** though lower cost electricity and fuels, increased food production, and environmental cleanup;
- **Revitalize the coal industry** and enhance national security by maintaining low cost energy supply from vast domestic coal resources; and
- **Constitutes a “no regrets” strategy for CO<sub>2</sub> control.**



The innovative MicGAS™ technology is based upon applying natural microorganisms adapted to convert coal into clean fuels under anaerobic conditions. Unlike the conventional coal gasifier, the solid residue from the MicGAS™ anaerobic treatment is not a waste, but is rich in organic humic matter.

The residual coal from this treatment is further subjected to biochemical process for extraction of humic acid. This valuable byproduct has applications as a fertilizer material and also in environmental remediation.