

CRITICAL NATIONAL NEED IDEA

Aluminum Energy could

be a pivotal factor in reducing our nation's dependence on oil.

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Aluminum Energy for Fuel Cells

Breakthroughs in chemistry and technology have provided the opportunity for aluminum, an abundant and fully recyclable metal, to be used as a fuel to generate electricity in fuel cells, both efficiently and economically.

In addition, using an energy source that is both plentiful and fully recyclable will dramatically enhance its utilization and provide benefits globally.

To fully understand the significance of these breakthroughs, it would be important to illuminate the nature of these discoveries.

For decades scientists have been attempting to unleash the extensive stored energy locked in aluminum (enthalpy - theoretical energy density 10.167kWh/kg), because it has one of the highest levels available in any metal or fuel. We can see the power of aluminum when its powder is ignited in fireworks.

Fortunately, the proposed technology has enabled this to become more viable and to be competitive in the energy marketplace, a phenomenon that has not been previously possible.

Having solved the major technical problems for production, the breadth of applications that can be undertaken advantageously is quite extensive. Furthermore, the technology and chemical analysis continues to be refined, adding to future efficiency.

I. History

Aluminum has been a most sought after source of energy for more than 50 years, because of its inherent high energy density, its being lightweight and its being recyclable.

Aluminum has already proven itself to be a viable material in battery applications.

The Zaromb cell, produced in 1960, stored 15 times the energy of a comparable lead acid battery. ^[6]

Fuel cells using different metals really began more than 25 years ago. The driving force in these endeavors was the need to find a reliable, lightweight power source for sophisticated, military and space applications. The weight and limited shelf life of traditional batteries was just not acceptable. Initial attempts, unfortunately, had substantial drawbacks due to corrosion. Other attempts led to the use of tin, indium, thallium, iridium or gallium to lower the corrosion. Since the year 2000 some companies, particularly Aluminum Power, Inc., as well as Voltek, Inc., and eVionyx, Inc., have attempted to produce small aluminum-air cells for portable applications. The challenge has been to manufacture cost competitive, efficient products. Most companies have

used aluminum alloys in production, at a significant cost increase. In addition, expensive additives were added to the mix. Both these issues hampered the recycling of the by-products and created unwanted wastes. These factors, combined with the inability to create an affordable final product, substantially reduced the general commercial viability for all but specialized uses.

II. Present Trends and Capabilities

Undertaking a completely new approach to the use of aluminum as the source of energy for fuel cells included the use of industrial aluminum and a more optimized electrolyte mixture to dramatically release the inherent energy. Because there were no alloys to separate it from, the resulting mix could easily be recycled (see an aluminum recyclable life cycle diagram below). Furthermore, the use of proprietary, but readily available, chemical formulations will simplify the process to a viable commercialized product.

At the present time there are two substantial technologies that utilize the use of aluminum as the key ingredient. One is known as the Alkaline Aluminum-Air Fuel Cell Technology and the other is the Hydrogen Production for Fuel Cell Technology.

While most other hydrogen-based fuel cell technologies rely on hydrogen stored in a pressurized gas or liquid form, these new technologies derive their power from water and a solid-state fuel. More energy can be liberated over a much longer period of time at a significantly reduced cost, because of the higher relative density of its power source. It is anticipated that aluminum-air fuel cells will be substantially simpler and lower in cost than others, such as PEMFC, Lithium Ion or Nickel-Metalhydride batteries.

Integrated into both these technologies are the crucial uses of both the on-board and the on-demand production of all the required energy. All the energy is held within the aluminum and water until it is requested. There are no outside storage units, nor any problem with stability or combustion.

A. Alkaline Aluminum-Air Fuel Cell

The aluminum-air fuel cell is composed of an aluminum anode set in an aqueous alkaline solution and utilizes a gas diffusion electrode/cathode. The emission-free oxidation of aluminum by oxygen from ambient air provides an efficient power supply. The safe and efficient proprietary components can be housed in a fully self-contained unit. One key to this technology is the use of two quickly replaceable cartridges, one containing the aluminum anode and the other containing an electrolyte mix with water. Once the anode cartridge is replaced, it can be recycled back to aluminum dozens of times for many years.

B. Hydrogen for Fuel Cell

The hydrogen production system is a fully self-contained unit that is capable of producing a virtually unlimited environmentally safe source of hydrogen and it requires no high-pressure storage tanks. This creates unique advantages for utilizing this system, including military applications or for any hydrogen production and storage requirements (perhaps for extensive transportation "refueling" stations). On a technical note, it uses fully recyclable, relatively low cost and easily available chemical components and displays a highly efficient hydrogen output. The high performance, moderate cost, and the level of enhancements in the availability of an ongoing source of pure hydrogen without any pressurized containment, makes this system unlike any other on the market today.

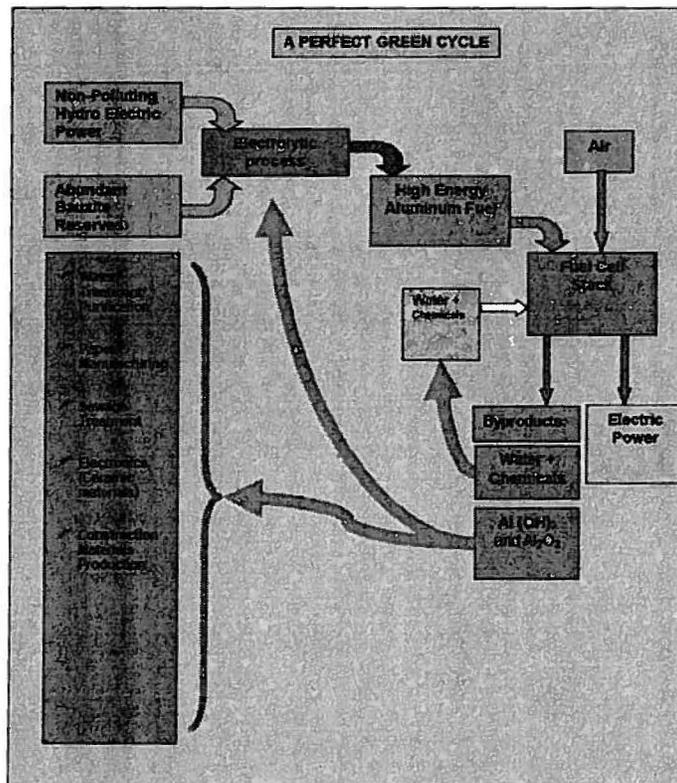
III. The Green System

There are no polluting emissions with energy generated by the alkaline aluminum-air fuel cell and hydrogen production and storage technologies. All similarly designed future products should run continuously, quietly, and efficiently, while delivering a high specific energy at a relatively low cost. The new technologies should be more economically competitive than many other green technologies.

Both the electrical energy production cycle and the hydrogen production cycle, create byproducts that include: water and chemicals, which are recycled back into the fuel cell operation; aluminum oxide (Al_2O_3) and aluminum hydroxide $Al(OH)_3$, which are used in a number of industries from water purification and sewage treatment to paper manufacturing and electronics. They can also be fully recycled back into aluminum. No residual waste products destined for a landfill are generated nor are any pollutants emitted into the air.

Logistically, the storing, shipping, and distributing of anode cartridges (aluminum plates) and chemicals (dry powder) are much safer than the pressurized hydrogen or methanol used by existing Fuel Cell Power Systems. Furthermore, there should be no safety issues either for travel on airplanes or for any military applications.

Unlike certain other methodologies, which use methanol, natural gas or other fossil fuel products, these technologies will have no environmental or health side effects while generating their electricity or hydrogen. In summary, they deliver electrical energy with zero pollution, complete safety and full recycling.



The introduction of this innovative technology will add a significant boost to green electrical capacity and will have a positive impact on the environment; reducing carbon dioxide, other gas emissions and pollution.

IV. Applications – Viability and Vision

The diverse applications that new technologies can be integrated into include almost all activities requiring the eventual production of energy, hydrogen and electricity. Given its inherent environmental advantages, relatively good economics and availability, aluminum should eventually become an important part of the renewable energy industry. Obviously, the viable commercialization of the technologies is still in its initial stages, but the potential remains and the most difficult technical barriers have been overcome. Certainly the opportunities mentioned below reflect only a part of the potential.

A. Military

The military has been interested in aluminum as a source of energy for fifty years. They understand the critical advantages of its inherent energy and being lightweight, portable and vastly abundant. The mobile soldier, with his/her multitude of electronic equipment, would be an immediate benefactor. The sophisticated devices used in the field or in remote activities require the benefits integral to these technologies.

B. Hydrogen Storage and Delivery

Hydrogen has a low energy density relative to volume, making it more difficult to store a sufficient amount within a reasonably sized space and it is innately unstable. Delivering or transporting hydrogen in high-pressure storage tanks is cumbersome, expensive and would restrict its use in many places. Using water as the hydrogen source until the hydrogen is released by its chemical reaction with aluminum greatly relieves these problems and eliminates storage, delivery and/or transportation difficulties.

C. Batteries

Traditional rechargeable batteries have a limited shelf life, as well as a limited output capacity and, hence, quickly require an auxiliary power source. Aluminum-air fuel cells may be as much as ten times as dense compared with lead-acid batteries and occupy a fraction of the space or weight. They can be mechanically recharged to its original capacity by simply replacing its cartridges. Numerous uses for uninterrupted reliable remote power include computer data storage banks, critical manufacturing facilities, bank ATMs, telecommunication systems and safety lighting.

D. Portable

The possibilities for use in this arena are greatly enhanced by the longevity of the power output. Laptop computers could have remote operations for more than 24 hours and the same is true for most of the innumerable portable electric devices available today. Any isolated location could have the services it requires without establishing uneconomical electrical connections to the grid or building a huge infrastructure.

E. Stationary

The possibilities for the individual homeowner, supermarket or manufacturing plant (the residential, commercial and industrial applications) to establish an independent source of power off the main electrical grid as either a primary or secondary source of energy is quite viable. The unattractive presence of some fuel generators, with their inherent noise or pollution, is eliminated and replaced with a quiet, unobtrusive unit with no pollution during its operation, providing for the opportunity to place this power source indoors.

F. Transportation

The unique advantage of combining both the inherent energy in aluminum and water with the on-board/on-demand methodology creates an opening for initializing the utilization of the aluminum-air technology and hydrogen generation for use in the bicycle and scooter; golf-car and forklift; boat and yacht; and even the automotive industry. By utilizing the hydrogen generated, in a safe stable environment, the enormous storage and delivery problems are eliminated. The concerns for having to reinvent the infrastructure for hydrogen cars also subside. Obviously, the technical complexities will take time and effort, but the critical points or problems are feasible.

G. Power Plants

The enormous amount of power generated globally creates an infrastructure that cannot be duplicated or replaced in any foreseeable future. However, the need to establish operations in remote locations or for special purposes allows for the possibility of erecting a power operation with a limited amount of infrastructure. Furthermore, delivering the power source becomes significantly easier than building major pipelines or electrical lines. In addition, with a potential global carbon tax being considered, the economics of using aluminum energy as an alternative or as a complimentary part of the solution becomes more crucial. This renewable aluminum energy can become an important part of the energy mosaic.

V. Conclusion

Having reviewed the history of aluminum energy for fuel cells and its present capabilities, one must conclude that the utilization of aluminum for fuel cells should become an integral part of the solution for an economically, clean, non-polluting source of energy. Its ability to be used in a wide range of applications lends itself to the possibility that one or more of its inherent characteristics will be a most efficient choice for any number of critical uses. Given its abundance, lightweight and its being fully recyclable, the opportunities for the commercialization of the multiple technologies are quite evident. Certainly numerous design and manufacturing issues still exist, but because the critical technological challenges have been resolved, the potential is certainly quite high.

APPENDIX I.

Aluminum as Energy Storage Bank

Aluminum is one of the most plentiful materials on earth. It has a relatively low basic cost and it also has one the highest inherent electrical storage charge per unit weight. There is no cause for concern over possible depletion or exhaustion of the raw material, as 7.3% of the earth's crust is made up of aluminum compounds. Aluminum is so easy to recycle again and again, that it maintains a high value throughout a product's life.

The beginning of the 21st century has so far been characterized by a growing instability in global, political and economic situations. These factors prompted a sharp increase in the demand for reliable non-fossil energy. The severe urgency of having an alternative power source became particularly obvious during multiple massive blackouts both in North America and Europe.

"Inefficient use of energy depletes natural resources and may threaten climate change. While aluminum's attributes in saving energy are highly publicized, perhaps less well known is the material's potential role in generating energy." [1]

"Aluminum is an **"energy bank"** - the original energy input can be recovered again and again every time the product is recycled. Aluminum can be recycled profitably and repeatedly without loss in quality. Energy is stored in aluminum products and can be re-used. The recuperation of used aluminum products is thus both energy-efficient and cost-efficient for the industry." [1]

"More than 55 percent of the world's aluminum production is powered by renewable hydro-electric power. It is a material that can be profitably recycled without loss of quality, for use by future generations. It is its recyclability, as well as its applications, which justify the significant energy required initially to produce primary aluminum." [2]

The advantages of aluminum can be summarized as follows:

- Abundance
- Low Cost
- High Energy Storage
- Lightness

Aluminum compounds (aluminum oxide and aluminum hydroxide), are commonly used in a number of industries: from water purification and sewage treatment to paper manufacturing and electronics. They can also be fully recycled back into aluminum. No residual waste products destined for a landfill are generated nor are any pollutants emitted into the air. For instance, WHO (World Health Organization) recognized the beneficial effects of the use of aluminum as a coagulant in water treatment to remove unwanted material, including several organisms known to cause disease.

“Aluminum in its everyday form appears to be inert and the thin layer of aluminum oxide that coats the pure metal is a very stable and rugged shell that is responsible for aluminum’s stability at standard atmosphere conditions. Breaking through this barrier and activating the aluminum is/was a key challenge facing the scientists. Rather than rely on ultra pure (99.999 percent) aluminum as the fuel, they chose to alloy the metal and produce alloyed metal plates for use in the cells.” [4]

To become economically viable, the old technology, consisting of expensive anodes and intrinsic additives, had to be completely overhauled. The new Aluminum-air fuel cell technology had to overcome the following challenges:

- Dramatically reduce the cost of anodes, completely eliminating the use of alloys. (Each extra alloy additive increases the cost of the anode two to three fold).
- Completely eliminate the use of non-recyclable intrinsic additives, such as indium, gallium, tin and thallium, etc., thereby dramatically reducing the cost of both production and recycling.

The new Aluminum-Air Fuel Cell and Hydrogen Production and Storage technologies use completely new approaches for design and production:

- 1. Using industrial aluminum plates with no alloys;**
- 2. Using balanced, completely recyclable electrolyte with proprietary additives.**

Benefits for Aluminum Production Industry.

“More than 55 per cent of the world’s primary aluminum (from alumina) is produced using hydro-electric power which is clean, CO₂ free and renewable: e.g. over 80% for Russia and 100% for Norway. Also when energy shortages develop, power can be diverted from aluminum electrolysis to supply the power grid, thus helping to reduce peak period prices for other power users and reduce the need for the construction of marginal peak period electrical generating capacity.” [2]

“Currently aluminum production process uses two kinds of energy:

1. Energy from fossil fuel or “dirty energy”, used for alumina production from bauxite, and requires ~ 13mJ or 3.6kWh for production of 1kg of alumina;
2. Hydro Energy or “Green and renewable energy”, used for production of aluminum from alumina (electrolysis), whereas production of 1kg of aluminum requires 3 kg of alumina.”[2]

There are number of benefits of using aluminum as the source of energy – “energy bank”.

- 1) Using Aluminum Oxide and Aluminum Hydroxide, the byproducts of the innovative technologies, in the aluminum production process, will lead to conservation of energy and the cost reduction of aluminum production; completely eliminating “dirty energy” currently being utilized, e.g., from coal, petroleum, etc.; using only renewable and recyclable energy provided by hydro-electric power plants.
- 2) Using aluminum and water as an energy storage and distributor through alkaline aluminum-air fuel cell and hydrogen production for PEMFC will achieve the following:
 - i) Reduce criteria pollution
 - ii) Reduce carbon emissions
 - iii) The aluminum produced can be stored, distributed and transported anywhere safely.
- 3) New technologies do not produce any pollutants. The Aluminum byproducts (Aluminum Oxide and Aluminum Hydroxide) are fully recyclable. The electrolyte solution is non-toxic.
- 4) The use of aluminum as a source of energy will provide a tremendous value added opportunity for a wealth of applications and will dramatically enhance their efficiency and capabilities.