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Bloom Energy Technology

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Abstract— *Historically, businesses have been required to install many different types of energy technologies to address all their energy needs. To ensure power reliability, they purchase costly backup solutions. to increased power quality, they purchase costly power conditioning equipments. If they simply wante clean power, Then they should installed solar panels or purchase renewable energy credits.*
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I. INTRODUCTION

What is a fuel cell? A single fuel cell is made up of an anode and a cathode with an electrolyte in the middle, Fuel such as natural gas, biogas, or hydrogen is passed into the anode side and an oxidant is passed into the cathode side causing a reaction that moves electrons into the fuel cell's circuit, thus producing electricity. There are several types of fuel cells, but the primary focus in this article is on solid oxide fuel cells (SOFC) and, more specifically on bloom box, produced by bloom energy.

The technical roots of fuel cells began in the 1930s when two Swiss scientists experimented with zirconium and other elements as electrolytes. In the 1950s, GE and some other companies started small scale research projects. The bloom box: A solid oxide fuel cell involving solid oxide fuel cells. Projects were discontinued because cell materials melted, short-circuited, and had high electrical resistance inside of them. In 1962, the first federally funded research contract was awarded to Westinghouse to study zirconium oxide and calcium oxide based fuel cells.

Oxide fuel cell system operated for four years. The record for an individual fuel cell staying operational is 8 years. Presently many types of fuel cells have been developed. All of them are extremely expensive, with the more cost competitive running about 15-20 times the cost of a typical gas turbine generator. Currently, the DOE's SECA program is attempting to develop solid-state fuel cell modules that cost no more than $700/kW and large systems that are greater than 100 MW.

Department of Energy's Solid State Energy Conversion Alliance (SECA) in the fall of 1999, DOE initiated the SECA initiative to bring together government, industry, and the scientific community to promote the development of environmentally friendly solid oxide fuel cells. Most of the technologies, systems, and materials were focused on large-scale (greater than 100 MW) stationary power generating units that would gasify coal to create a feedstock for the SOFC units. Until 2007 the system cost target was $400/kW so that it would compete favorably with natural gas turbines. Having come nowhere close to the target, a new cost target of $700/kW was established. The original four commercial teams are down to three, with Siemens having dropped out. DOE now describes SECA as formed to accelerate the commercial readiness of SOFCs in the 3 kW to 10 kW range for use in stationary, transportation, and military applications. Next year Delphi (one of the commercial teams) will be commercializing a 3 kW APU that generates electricity for heavy-duty commercial trucks in-cab electrical accessories. The Solid Oxide Fuel Cell (SOFC) are mainly two types such as, solid oxide and hydrogen, have emerged as the fuel cell types of greatest commercial interest. Both types have been heavily subsidized, hydrogen primarily in automotive applications, and more recently, Seattle City Light 2010 Integrated Resource Plan solid oxide systems as a potential source of distributed power generation. We will examine in depth the solid oxide fuel cell.

The solid oxide fuel cell has gained recent attention for having potential applications in commercial and residential power. The diagram and explanation below showing a solid oxide

Fuel cells powered by pure hydrogen are from the Smithsonian Institution. Solid Oxide fuel cells use a hard, ceramic compound of metal (like calcium or zirconium) oxides (chemically, O2) as electrolyte. Efficiency is about 60 percent, and operating temperatures are about 1000 degrees C (about 1800 degrees F). Cell output is up to 100 kW. At such high temperatures a reformer is not required to extract hydrogen from the fuel, and waste heat can be recycled to make additional electricity. However, the high temperature limits applications of SOFC units, and they tend to be rather large. While solid electrolytes cannot leak, they can crack. If natural gas is used as fuel instead of pure hydrogen, carbon dioxide and other off-gases are also produced.

II. BLOOM BOX ENERGY SERVER

Economics of the Bloom Solid Oxide Fuel Cell System Bloom Energy's "Bloom Box" Energy Server (ES-5000) is a solid oxide fuel cell-based generating system, which is generally powered by natural gas, with rated power output of 100 kW. Recent publicity may have created the impression that the Bloom Box is available for residential power generation and that it will usher in a new era – a paradigm shift of distributed power generation. However, while the Bloom Box is currently being tested and debugged at several California commercial sites, Bloom Energy specifically states that "at this time" it is not interested in residential applications. Bloom Energy's sales force only talks to companies with facilities in California that spend at least $25,000 per month on electricity, which is the most attractive market given the current subsidy structure.

The Bloom Box ES-5000 Energy Server offered currently is at a quoted price of $800,000 and is a 100 kW unit. According to company sales people, the total purchase cost of the system and related project can be reduced by 80% using Federal and California State taxpayer subsidies and utility ratepayer subsidies and rebates.

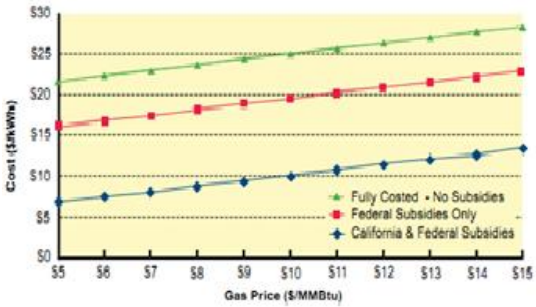

Fig.1 Bloom Box Cost depends on Gas Price and Subsidies.

The breakdown of these cost offsets and their Benefactors are:

• 30% ($240,000) using a federal taxpayer subsidy in the form of a tax credit.

• $250,000 using a California ratepayer rebate under the Statewide Self-Generation Incentive Program.

• 20% of the project cost (at least $160,000) using a California incentive bonus if the supplier is a California Supplier.

This $650,000 contribution using Federal and California State taxpayer subsidies and utility ratepayer subsidies and rebates reduce the buyer's net capital cost to $150,000 for a 100 kW system. Accounting for capital costs in a fair financial analysis requires some significant assumptions about a system's longevity. Solid oxide fuel cells have long faced challenges with durability, since they operate at 1800 degrees Fahrenheit.

Bloom Energy's versatile fuel cell technology is essentially a flexible energy platform, providing multiple benefits simultaneously for a wide range of applications. In addition to clean, reliable, affordable electricity, Bloom customers can realize a multitude of other advantages.

- Reverse Backup: Businesses often purchase generators and other expensive backup applications that sit idle 99% of the time, while they purchase their electricity from the grid as their primary source. The Bloom solution allows customers to flip that paradigm, by using the Energy Server as their primary power, and only purchasing electricity from the grid to supplement the output when necessary. Increased asset utilization leads to dramatically improved ROI for Bloom Energy's customers.
- Time to Power: The ease of placing Bloom Energy Servers across a broad variety of geographies and customer segments allows systems to be installed quickly, on demand, without the added complexity of cumbersome combined heat and power applications or large space requirements of solar. These systems' environmental footprint enables them to be exempt from local air permitting requirements, thus streamlining the approval process. Fast installation simply requires a concrete pad, a fuel source, and an internet connection.
- DC Power: Bloom systems natively produce DC power, which provides an elegant solution to efficiently power DC data centers and/or be the plug-and-play provider for DC charging stations for electric vehicles.
- Hydrogen Production: Bloom's technology, with its NASA roots, can be used to generate electricity and hydrogen. Coupled with intermittent renewable resources like solar or wind, Bloom's future systems will produce and store hydrogen to enable a 24 hour renewable solution and provide a distributed hydrogen fueling infrastructure for hydrogen powered vehicles.
- Carbon Sequestration: The electrochemical reaction occurring within Bloom Energy systems generates electricity, heat, some H_2O, and pure CO_2. Traditionally, the most costly aspect of carbon sequestration is separating the CO_2 from the other effluents. The pure CO_2 emission allows for easy and cost-effective

carbon sequestration from the Bloom systems.

Bloom is proud to deliver one of the most robust and dynamic energy platforms on the market today.

III. Electricity from Bloom Energy Server

A. How the Bloom Energy Server Fuel Cell Work?

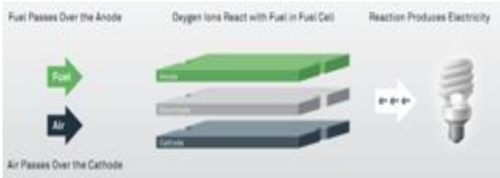

Fig.2 Construction of Bloom Energy Cell

Right now, the only box that Bloom is selling is a 100 kilowatt-hour energy server, which you can check out there. Inside there are thousands of solid oxide fuel cells each one able to power a light bulb. The cells are arranged in stacks, which are aggregated into modules, and so on, with a common fuel input. Right now, they are just for corporations like Google and Coca-Cola and run about $700,000 to $800,000 each. The goal's to get them down to three grand, where they'd be suitable for home use. That may still sound expensive, but they pay for themselves in 3-5 years, says Aaron, with an energy cost of 8-9 cents per kW hour vs. the 13-14 cents it typically costs in California. (It saved eBay $100,000 on their power bill.)But cost is where the real skepticism comes in. Fuel cells aren't a voodoo technology. They work. They produce energy. What analysts, and others, are wondering is whether Bloom's really cracked the secret to making them cheap, at least some day. The critic that CBS trotted out on 60 Minutes, Green Tech Media's Michael Kanellos, says that while there's a 20 percent chance we'll have a fuel cell box in our basements in 10 years, but "it's going to say GE."

B. Bloom Energy Server

The Bloom Energy Server (commonly referred to as the Bloom Box) is a solid oxide fuel cell (SOFC) made by Bloom Energy, of Sunnyvale, California, that can use a wide variety of inputs (including liquid or gaseous hydrocarbons produced from bio sources) to generate electricity on the site where it will be used. It is highly efficient, low cost and has lower polluting emissions. This type of fuel cell can withstand temperatures of up to 1800ºF, which would cause many other types of fuel cells to breakdown or need maintenance, and is highly advantageous for its smooth operation According to the company, a single cell (one 100 × 100 mm metal alloy plate between two ceramic layers) generates 25 watts.

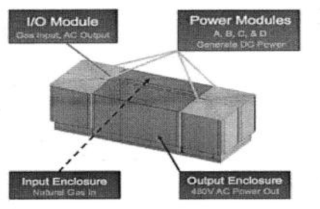

Fig. 3 Bloom Energy Server

Recently two hundred bloom energy servers have been deployed in California for a number of corporations like eBay, Google, Wal-Mart and many more.

C. Bloom Energy Server Technology

The Bloom Energy Server uses thin white ceramic plates (100 × 100 mm which are claimed to be made from "beach sand". Each ceramic plate is coated with a green nickel oxide-based ink on one side (anode) and another black (probably Lanthanum strontium magnetite) ink on the other side (cathode), According to the *San Jose Mercury News*, "Bloom's secret technology apparently lies in the proprietary green ink that acts as the anode and the black ink that acts as the cathode--" but in fact these materials are widely known in the field of solid oxide fuel cells (SOFCs). *Wired* reports that the secret ingredient may be yttria-stabilized zirconia based upon a 2006 patent filing (7,572,530) that was granted to Bloom in 2009; but this material is also one of the most common electrolyte materials in the field. which is assigned to Bloom Energy Corporation, says that the "electrolyte includes yttria stabilized zirconia and a scandia stabilized zirconia, such as a scandia ceria stabilized zirconia". ScSZ has a higher conductivity than at lower temperatures which provides greater efficiency and higher reliability when used as an electrolyte in SOFC applications. Scandia is scandium oxide (Sc_3O_2) which is a transition metal oxide that is sold between US$1400 to US$2000 per kilogram in 99.9% form. Current annual worldwide production of scandium is less than 2000 kilogram. Most of the 5000 kilogram used annually is sourced from limited former Soviet era stockpiles.

To save money, the Bloom Energy Server uses inexpensive metal alloy plates for electric conductance between the two ceramic fast ion conductor plates. In competing lower temperature fuel cells, platinum is required at the cathode.

IV. HISTORY

In October 2001, K.R Sridhar C.E.O had a meeting with John Doerr from the large venture capital firm Kleiner Perkins. Sridhar was asking for more than $100 million to start the company. Bloom Energy has received $400 million of start-up funding from venture capitalists, including Kleiner Perkins and Vinod Khosla.

The company, originally called Ion America, was renamed to Bloom Energy in 2006. Sridhar credited his nine-year-old son for the name, saying that his son believed jobs, lives, environment and children would bloom. One of the celebrities appearing at the product launch was Michael R. Bloomberg, who appeared by video link. Bloomberg's business news network covered the event, but was attributed every statement to "Bloom Energy".

The CEO gave a media interview (to *Fortune Magazine*) for the first time in 2010, eight years after establishing the company, because of pressure from his customers. A few days later he allowed a journalist (Lesley Stahl of the CBS News program 60 Minutes) to see the factory for the first time. On February 24, 2010, the company held its first press conference.

V. Bloom Energy Company Profile Details

Sr.No	Specification	Details
01	Type	Private
02	Predecessor	Ion America
03	Established year	2002
04	Founder(s)	K. R. Sridhar C.E.O , John Finn, Matthias Gottmann, James McElroy, Dien Nguyen.
05	Headquarters	Sunnyvale, California, USA
06	Key people	K. R. Sridhar (founder, CEO)
07	Products	regenerative solid oxide fuel cells
08	Net income	85 Million loss (2008)
09	Owner(s)	Kleiner Perkins (among others)
10	Website	http://www.bloomenergy.com/

VI. Installation Cost of Bloom Eergy

The current cost of each hand-made 100 kW Bloom Energy Server is $700,000–800,000. In the next stage, which will likely be mass production of home-sized units, Sridhar hopes to more than half the cost of each home sized Bloom server to under $3000. Bloom estimates the size of a home sized server as 1 kilowatt, although cNet News reports critical estimates recommend 5 kW capacities for a residence.

The capital costs according to Newsweek magazine is $7–8 per watt.

According to the New York Times (Green Blog), in early 2011 "... Bloom Energy ... unveiled a service to allow customers to buy the electricity generated by its fuel cells without incurring the capital costs of purchasing the six-figure devices. Under the Bloom Electrons service [4], customers sign 10-year contracts to purchase the electricity generated by Bloom Energy Servers while the company retains ownership of the fuel cells and responsibility for their maintenance. We are able to tell customers, You don’t have to put any money up front, you pay only for the electrons you use and it is good for your pocketbook and good for planet,[CEO K.R. Sridhar] said.

On 24 February 2010, Sridhar told Todd Woody of *The New York Times* that his devices are making electricity for 8–10 cents/kWh using natural gas, which is cheaper than today's electricity prices in some parts of the United States, such as California. Twenty percent of the Bloom Energy Server cost savings depend upon avoiding transfer losses that result from energy grid use.

Bloom Energy is developing Power Purchase Agreements to sell the electricity produced by the boxes, rather than sell the boxes themselves, in order to address customers' fears about box maintenance, reliability and servicing costs.

Fifteen percent of the power at eBay is created with Bloom technology; after tax incentives that paid half the cost eBay expects "a three-year payback period" for the remaining half, based on California's $0.14/kWh cost of commercial electricity.

The company says that first 100 kW Bloom Energy Servers were shipped to Google in July 2008. Four such servers were installed at Google's headquarters in Mountain View, California, which was Bloom Energy's first customer. Another installation is for five boxes to make up to 500 kW at eBay headquarters in San Jose, California. Bloom Energy states that their customers include Staples (300 kW - December 2008), Walmart

(800 kW - January 2010), FedEx (500 kW), The Coca-Cola Company (500 kW) and Bank of America (500 kW). Each of these installations (current or planned) is located in California.

A. Portable units

Writing for a *Wall Street Journal* blog, Rebecca Smith and Jim Carlton speculated that portable Bloom Energy Servers could be used instead of traditional generators by the armed forces. Sridhar plans to install Bloom Energy Servers in third world nations. Ex-Chairman of the Joint Chiefs of Staff, Colin Powell, now a Bloom Energy board member, said the Bloom Energy generators could be useful to the military because they are lighter, more efficient, and generate less heat than what the military uses now.

B. Feasibility

According to BBC tech blogger Maggie Shiels, Bloom Energy is "being very coy and playful about what it will reveal to the press". She quotes Michael Kanellos of Greentech Media regarding the general scope and feasibility of Bloom Energy's plans: fuel cells are not new technology and in order to succeed in the marketplace the Bloom Energy Server would need to be cheaper than existing types of renewable energy. If Bloom Energy can develop such a technology, Kanellos predicts that established energy firms such as General Electric would derive most of the profits due to greater ability to manufacture and market a product. Jacob Grose, senior analyst at Lux Research told Fortune Magazine that he doubts Dr. Sridhar has come up with a way of making these ceramic fuel cells cheaply enough to be truly revolutionary.

Bloom Energy Server technology is based upon stacking small fuel cells which operate in concert. USA Today claims that Bloom Energy has made a technological advance by developing stacked fuel cells where individual plates expand and contract at the same rate at high temperatures, however many other solid oxide fuel cell producers have solved that problem in the past. Scott Samuelsen of the University of California, Irvine National Fuel Cell Research Center questions how long the reliable operational life of Bloom Servers will be. "At this point, Bloom has excellent potential, but they have yet to demonstrate that they've met the bars of reliability." Lawrence Berkeley National Laboratory expert Michael Tucker told the San Jose Mercury News, "Because they operate at high temperatures, they can accept other fuels like natural gas and methane, and that's an enormous advantage... The disadvantage is that they can shatter as they are heating or cooling."

John Doerr, a venture capitalist, who has a large investment in the company, asserts that the Bloom Energy Server is cheaper and cleaner than the grid. An expert at Gerson Lehrman Group, wrote that, given today's electricity transmission losses of about 7% and utility size gas fired power stations efficiency of 33-48%, the Bloom Energy Server is up to twice as efficient as a gas fired power station. In a follow up story entitled "Bloom Box: Segway or savior?" Fortune noted on 24 February 2010 that "Bloom has still not released numbers about how much the Bloom Box costs to operate per kilowatt hour" and estimates that natural gas rather than bio-gas will be the primary source of fuel for Bloom Energy Servers. Jonathan Fahey of Forbes wrote: Are we really falling for this again? Every clean tech company on the planet says it can produce clean energy cheaply, yet not a single one can. Government subsidies or mandates keep the entire worldwide industry afloat. Hand it to Bloom, the company has managed to tap into the hype machine like no other clean tech company in memory.

C. Efficiency

Current gas fired power stations convert chemical energy to thermal energy to mechanical energy to electrical energy. A modern combined cycle gas turbine power plant (CCGT) can reach 60% overall efficiency. Sridhar says Bloom Boxes convert chemical energy to electrical energy in one step, and are more fuel efficient than current gas fired power stations and also reduce transmission/distribution losses by producing power where it is used.

Each Bloom Energy Server provides 100kW of power, enough to meet the base load needs of 100 average homes or a small office building.

Sridhar also said the boxes will have a 10 year life span, although that could include replacing the cells within the boxes during that time period. The CEO of eBay says Bloom Energy Servers have saved the company $100,000 in electricity bills since they were installed in mid-2009, yet Paul Keegan of Fortune calls that figure "meaningless without the details to see how he got there.

VII. CRITICISMS

The high capital costs of the Bloom $7–8/watt make the economic feasibility of the bloom questionable. Over ten years the bloom will generate 8,760,000kWh. At 50% efficiency, it will consume 600,000 therms of natural gas. With a natural gas price of $0.86 per therm, it would cost $520,000 in fuel with a capital cost of $700,000. This makes a total cost of $1,220,000 and ten year electricity cost of $0.14/kWh. These numbers are highly optimistic and assume zero maintenance, zero downtime, minimal installation costs, and optimistic efficiency.

VIII. COMPETITION

A Gerson Lehrman Group analyst wrote that GE dismantled its fuel cell group five years ago and Siemens have almost dismantled theirs. United Technologies is the only large conglomerate that has fuel cell technology that could compete with Bloom Energy. Toshiba only has technology to provide energy for a small device, not a neighborhood.

Katie Fehrenbacher of Business Week reports that Sprint Nextel owns 15 patents on hydrogen fuel cells and is using 250 fuel cells to provide backup power for its operations. Sprint has been using fuel cell power since 2005. Last year Sprint's fuel cell program received a grant of over $7 million from the United States Department of Energy. The Sprint program has partnered with ReliOn and Altergy for fuel cell manufacture and with Air Products as a hydrogen supplier. Business Week reported that a German fuel cell firm called P21, which is based in Munich, has been working on similar projects to supply backup power for cellular operations. United Technologies makes fuel cells costing $4,500 per kilowatt.

In October 2009 the Department of Energy awarded nearly $25 million in grants for research and development of solar fuels, which Michael Kannelos notes in Wired, may be similar technology to the solar cells in Sridhar's description of the Bloom Energy Server. Department of Energy grant recipients included a variety of startup companies and universities.

According to an article in New Scientist, there is a claim stating the Bloom Box is "electrolyte-supported" and based on that, there are at least two well-established companies, Topsoe Fuel Cell and Ceres Power, already rolling out products with more advanced non-electrolyte-supported cells. Ceres having a four-year program to install 37,500 units in the homes of customers of the UK's British Gas.

Ballard Power's comparably scaled products are based on proton exchange membrane fuel cells. Ballard's 150 kW units are intended for mobile applications such as municipal buses, while their larger 1 MW stationary systems are configured from banks of 11 kW building blocks.

Another competitor that already has product in-market in Europe and Australia is Ceramic Fuel Cells , with an efficiency of 60% for the power-only units; these fuel cells are based on proven technology spun off from Australia's CSIRO.

XI. Conclusion

At this time, there is no compelling reason for City Light to pursue any interests in solid oxide fuel cell systems. Bloom Energy has the only commercially available system, the ES-5000 Energy Server, and it is available only to facilities located in California with very specific energy requirements. This narrow market focus parallels the structure of major subsidies from state and federal taxpayers and utility ratepayers. No system is available in Washington for either residential or commercial applications. Because this natural gas-based system is vastly more expensive than any alternate source to City Light (or their customers), and because City Light's current power portfolio is very nearly free of carbon dioxide or other greenhouse gas emissions, the possible advantages of a Bloom Box all fail. City Light's electricity sources are cleaner and less expensive. No renewable resource presently under consideration by City Light is as expensive as the Bloom Box, which is not renewable. The Department of Energy and various companies and researchers have, for over a decade, worked to reduce the cost and improve the reliability of these systems. There appears to be no near-term breakthrough that should substantially change City Light's outlook.

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