Sustainable Energy for the 21st Century: A Case for Action

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1 Executive Summary

As the global demand for energy continues to grow, businesses and consumers are not only requiring more energy, but they are also under increasing pressure to use cleaner and more reliable sources of power. The current system and the related costs and inefficiencies associated with centralized power primarily based on fossil-fuel sources is increasingly less capable of meeting the growing demand. Bloom Energy Servers® can help address many of the economic and environmental concerns by providing on-site, clean, reliable electricity. Bloom's technology empowers customers to generate their own electricity and reduce their CO_2, NOx and SOx emissions. Bloom Energy Servers release 735-849 pounds of CO_2 per megawatt-hour (MWh) while the average U.S. grid emission rate is 1,520 and 1,620 including 6% losses due to transmission and distribution inefficiencies.[1] By using a highly efficient electrochemical process, Bloom reduces carbon emissions by 50% compared to the U.S. grid. When Bloom Energy Servers run on biogas, the electricity generated is carbon neutral. A recent report by Itron on the California Self-Generation Incentive Program (SGIP) discusses the net-reducing effect on greenhouse gas emissions and points out that the electrical efficiency of electric-only fuel cells is greater than grid-delivered electricity.[2] Additionally, the Bloom Energy Servers do not require any water during normal operation. Bloom fuel cells also provide reliable power that can be used as a primary or secondary power source and can eliminate the need for backup diesel generators. This paper outlines the energy challenge and the opportunity to develop a sustainable energy system for the 21st Century.

[1] eGRID 2014, http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html
[2] http://www.cpuc.ca.gov/NR/rdonlyres/25A04DD8-56B0-40BB-8891-A3E29B790551/0/SGIP2012ImpactReport_20140206.pdf

2 Context: Global Energy Demand is Booming

The world has a voracious and growing appetite for energy that today's mix of conventional and renewable power sources cannot reliably meet. The key drivers of the increasingly fragile equation between energy supply and demand are population and economic growth. The UN projects global population will surge from 7 billion today to over 9 billion by mid-century. Meanwhile, giants like China and India will require vast quantities of reliable power to keep their ascendant economies humming. It is also reasonable to expect that a significant portion of the 1.5 billion people in the developing world who now live without electricity will gain access.

Population growth alone may align with a disproportionate rise in energy consumption; during the second half of the 20th Century, U.S. population increased by 86 percent while electricity usage grew nearly tenfold and average per-capita use more than quintupled.[3]

In this new century, the power needs of our digital lives only add to explosive demand. Clearly, new energy paradigms are needed. We seek not only more electricity, but cleaner electricity as well. Against a growing awareness of pressure on the global environment, sustainability is becoming "table stakes" for development. Across the globe, nations are on the hunt for more reliable, affordable, round-the-clock power and are increasingly putting a premium on renewable sources to meet greenhouse gas-reduction regulations. One thing is clear: there cannot be clean water and clean air without clean energy.

3 20th Century Grid vs. 21st Century Needs

Today's options, however, rely on a power grid from the last century that leaves users vulnerable to outages, uncertainty and undesirable environmental consequences. The system is brittle, inefficient and inadequate for 21st century growth. By burning fuel for steam that rotates turbines, which in turn run generators that send electricity through power lines to distant users, conventional power plants consume 3 to 4 units of fuel per unit of electricity delivered.[4] This type of inefficiency is unsustainable and no longer able to handle the increasingly grueling demand.

The grid relies largely on dirty fuels, most significantly coal, which generates 38 percent of U.S. electricity, but which itself faces future challenges: growing competition from natural gas and government regulations that can present utilities with an all-or-nothing choice between making expensive upgrades to plants or closing them.

The existing grid fails on a range of sustainability issues that are critical to a reliable and sustainable energy future: air quality, water and land pollution, water and land resources, greenhouse gases, inefficiency and waste.

[3] http://www.eia.gov/FTPROOT/multifuel/038499.pdf
[4] Rocky Mountain Institute, "Small is Profitable," http://www.smallisprofitable.org/PartOne.html

4 A New Solution: Electricity without Combustion

In a revolutionary addition to the world's power mix, Bloom Energy has commercialized a way to generate clean, reliable, quiet, on-site electricity while minimizing environmental impact. Bloom offers one of the most electrically efficient distributed generation technologies in the world. Because Bloom Energy Servers are installed at the point of consumption, they eliminate the loss of energy to transmission and distribution.

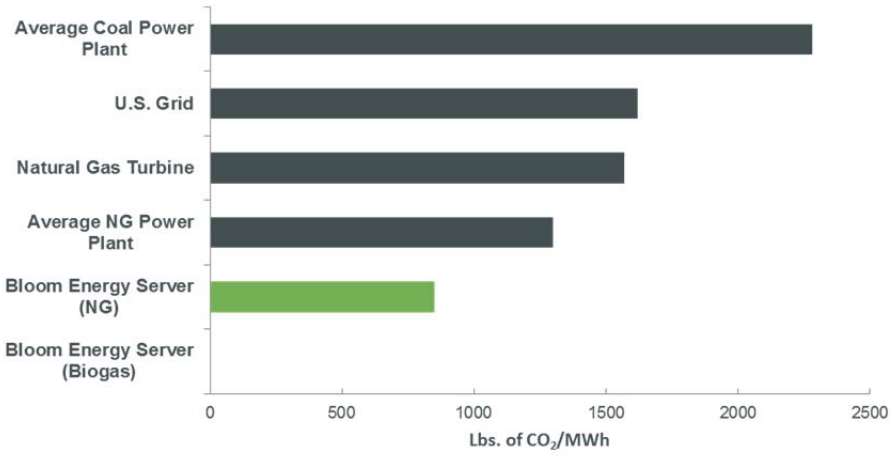
The Bloom Energy Server, or Bloom Box, delivers a 24x7 solution that needs no backup from other energy sources and requires almost no water. The small physical footprint reduces environmental resource impact and works well in more densely populated urban areas. "This kind of technology is a win-win economically and environmentally," writes Jim Marston, vice president of the Environmental Defense Fund's Energy Program, "one from which all sectors stand to benefit."[5]

Bloom delivers a variety of sustainability benefits that make it a favorable power supply for facilities of any size. Rooted in NASA's Mars mission technology, Bloom uses fuel cells to produce electricity from an electrochemical reaction rather than combustion. This technology dramatically reduces emissions of greenhouse gases, eliminates other pollutants such as NOx and SOx, and spares the tremendous water usage typical of power plants. Bloom Boxes can be fueled by natural gas or by renewable fuels like biogas, providing a clean alternative to the fossil fuel plants that dominate America's electricity production.

5 Reduced Carbon Dioxide

The electrical efficiency of the Bloom Energy Servers significantly reduces carbon emissions compared to the U.S grid. When fueled with biogas, the Bloom Energy Server is a carbon-neutral source of electricity. When using natural gas, it releases 735-849 pounds of CO_2 per MWh, a fraction of the 2,281 pounds and 1,300 pounds (including T&D losses) produced by coal-fired plants and a natural gas combustion turbines,

Figure 1. Bloom Energy Emissions Comparison



[5] http://www.edf.org/energy/innovation/fuel-cell-technology

respectively.[6] A recent report by Itron on the California Self-Generation Incentive Program (SGIP) compares a number of distributed technologies and their impact on greenhouse gas emissions. The report found that electric-only fuel cells have a net-reducing effect on greenhouse gas emissions and that the electrical efficiency of these fuel cells is greater than grid-delivered electricity.[7]

6 Reduced SOx, NOx, and Particulate Emissions

Due to the clean and efficient operation of Bloom's electrochemical process, Bloom Energy projects generate negligible emissions and often do not require additional premitting. Without pollution emissions that come from combustion causing smog and acid rain and harm human health, Bloom technology provides a clear advance from coal-fired plants which produce 13 pounds/MWh of sulfur dioxide and 6 pounds/MWh of nitrogen oxides on average. Bloom Energy Servers are also free of mercury and toxic emissions that plague coal-fueled plants and are targeted by new federal regulations to protect public health.

Bloom's ultra-low emissions also outperform natural gas turbines which produce 0.1 pounds/MWh of sulfur dioxide and 1.7 pounds/MWh of nitrogen oxides, according to the Environmental Protection Agency.[8]

In California, where environmental standards are especially stringent, Bloom's technology has earned a "distributed generation certification" under California Air Resources Board standards for exemption from air quality permitting rules.[9] The program allows exemption from district permit requirements for electrical generation technologies that meet strict emission standards.[10]

7 Reduced Water Usage

Bloom's technology uses no water during normal operation beyond a 240-gallon injection at start up. Compared to the generation of 1 MW of Bloom, the average U.S. coal plant uses 58.2 million gallons of water per 200 kW annually; combined cycle natural gas plants use 420,000

Figure 2. Bloom Energy Water Comparison

Generation Type	Gallons per MWh	Annual Gallons (per MW of Bloom equivalent generation)
Bloom Energy Server	0	.001 million
Combined Cycle Nat Gas Plant (cooling tower)	250	2.1 million
Coal Power Plant (open loop cooling)	35,000	291 million
U.S. Grid	10,360	86 million

[6] http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11
[7] http://www.cpuc.ca.gov/NR/rdonlyres/25A04DD8-56B0-40BB-8891-A3E29B790551/0/SGIP2012ImpactReport_20140206.pdf
[8] http://www.epa.gov/cleanenergy/energy-and-you/affect/coal.html and http://www.epa.gov/cleanenergy/energy-and-you/affect/natural-gas.html
[9] http://www.arb.ca.gov/energy/dg/eo/dg036.pdf
[10] http://www.arb.ca.gov/energy/dg/dg.htm

gallons per 200 kW annually.[11] A 1MW Bloom Energy project would save up to 86 million gallons a year compared to the U.S. Grid.

8 Increased Reliability

Since Bloom Energy Servers can operate independent of the grid, reliability is a key advantage. Grid failures affecting at least 50,000 consumers increased by 41 percent during the 1990s, according to Forbes — a trend that persists today.[12] The catastrophic outages that plagued the East Coast during the summer of 2012 have been directly linked to weaknesses in the grid.[13] Companies are forced to make significant investments in expensive backup equipment, yet there are significant environmental impacts associated with diesel generators – localized particulate emissions tend to spike during grid outages and fuel storage can present risks of petroleum spills. Meanwhile, battery-based back-up systems often involve large amounts of lead and hazardous acids. “This fuel-cell technology could make obsolete the need to back up grid power with batteries or generators – a requirement for hospitals, data centers, public-safety facilities, and other facilities that can’t afford a power outage,” said Carl Pope, the former chairman and executive director of the Sierra Club. “That 20 percent of America’s energy consumers could be served more cheaply and cleanly with Bloom Energy Servers.”[14] Bloom Energy Servers require a smaller physical footprint as compared to the vast land needs of solar and wind farms, nuclear reactors and conventional power plants that disrupt wildlife habitat, tarnish landscapes and can harm local ecology.

Each Bloom Energy Server provides 200 kW of power, enough to meet the baseload needs of 160 average US homes or an office building, day and night, in roughly the footprint of a parking space. The system’s modular design means that facilities needing more power can simply add more Bloom Boxes. The on-site solution is not only compact but offers an environmentally-friendly appearance and operation, achieved by Bloom’s quiet, non-vibrating sleek boxes. Additionally, the majority of the metals, including sheet metal, aluminum, etc. and fuel cell components are recycled and refurbished for new systems.

9 Cleaning the Cloud

Numerous companies, including those seeking to lower their carbon footprints, are realizing the benefits of having a reliable on-site power source in Bloom Energy Servers. The ascendance of

[11] http://www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/ucs-power-plant-database.html#.VJC_UyvF-RZ
[12] EIA Form 860, Bloom Analysis, and http://www.forbes.com/sites/williampentland/2012/06/24/why-the-bloom-suit-is-bad-for-america/print/
[13] http://spectrum.ieee.org/energywise/energy/the-smarter-grid/outage-recovery-and-market-manipulation-are-still-problems
[14] http://sierraclub.typepad.com/carlpope/2010/06/tis-the-gift-to-be-simple.html

cloud computing and exploding data-storage needs has prompted some technology companies, in particular, to step up in search of sustainable solutions.

Data centers, however, have until now largely relied on coal as a cheap source for their power needs, despite a dismal CO_2 and air pollutant profile and wasteful transmission costs. Data centers currently consume up to 2 percent of all global electricity, a slice of the pie that is growing at 12 percent a year, a study by Greenpeace found.[15]

Even while some data companies understand that energy is a key factor in environmental stewardship, the sector as a whole still seeks to define green as being more efficient rather than being more sustainable, the Greenpeace study reports. “This failure to commit to clean energy in the same way energy efficiency is embraced is driving demand for dirty energy and is holding the sector back from being truly green,” according to the study.

eBay Inc. became the first major tech company to turn to an off-the-grid solution for its primary energy source with its Utah data center powered by 6 MWs of energy generated on site by Bloom Energy Servers. “It is really throwing out the way people have done it in the past,” Dean Nelson, eBay’s vice president of global foundation services, told The New York Times. “You can build a better mousetrap.”[16]

10 The Evolution of Energy

This new century brings unprecedented power demands coupled with ever tighter environmental regulations, challenging us to create a new energy economy. New power sources must be efficient in every sense, clean, and able to reliably compensate for the shortcomings of the power grid. While other alternative forms of generation each provide certain advantages, only one, the Bloom Energy solution, meets — and exceeds — the multiple challenges of our time.

[15] http://www.greenpeace.org/international/Global/international/publications/climate/2011/Cool%20IT/dirty-data-report-greenpeace.pdf
[16] http://www.nytimes.com/2012/06/21/technology/ebay-plans-data-center-that-will-use-alternative-energy.html