CLEAN ENERGY MARKETS

FIVE TRENDS TO WATCH IN 2002

BY JOEL MAKOWER
AND RON PERNICK

JANUARY 2002

CLEAN EDGE
THE CLEAN-TECH MARKET AUTHORITY

INTRODUCTION

Amid turbulence and uncertainty across most investment markets, investor interest in clean-energy companies remains strong, from angel investors to venture capital firms to investment banks and strategic investors. The reasons are many and varied, ranging from investors' natural curiosity in "the next big thing" to a vast confluence of political, technological, and social forces that make clean energy a compelling investment strategy.

Perhaps most compelling is the size and scope of the energy marketplace. In the US alone, energy represents an annual US$350 billion market. Clean-energy technologies – including solar photovoltaics, wind power, microturbines, and fuel cells – represent a fast-growing segment of the marketplace. Wind power and photovoltaics are two of the highest-growth technology sectors on the planet, growing by more than 30% annually. In many regions, wind power is now the most cost-competitive new energy source, averaging US4.5 cents per kWh – with construction, operation, and maintenance costs running less than most fossil fuel-powered plants.

Our most recent forecasts see clean-energy markets growing from less than US$7 billion in 2000 to more than US$82 billion by 2010. The market for energy-efficient goods and services – already US$33 billion in the US – will grow by more than 8% a year for the next three years and will include a growing percentage of clean-energy goods and services.

Beyond the numbers are a variety of diverse factors that have converged to place clean-energy technologies and companies in the limelight:

- **Security issues**, which have become central to US and international policy in the aftermath of September 11, make clean and distributed energy sources a critical part of any balanced and secure energy portfolio. Solar PV and fuel cells are excellent distributed energy sources, which allow energy to be developed on-site, without dependence on vulnerable centralized power plants and electricity grids. And cheap and abundant sources like wind power are a safe alternative to oil, natural gas, and nuclear plants that are volatile terrorist targets.
- **Energy uncertainty**, exemplified by last year's electricity shortages in California, has increased demand for "distributed generation," technologies such as microturbines, fuel cells, and solar photovoltaics, which enable electricity to be generated at or near where it is needed, rather than being shipped hundreds of miles over power lines.
- **The need for increased power reliability and quality** in many business applications – spurred by the growth of electronics and "always on" products – has made some distributed energy technologies an attractive and affordable alternative. The standard of acceptable power quality is rapidly mov-

ing from "four nines" (99.99%) reliability — or roughly 53 minutes a year of power outages — to "nine nines" (99.9999999%), or about 3 milliseconds of annual outages.

- **Technological advances**, including continued innovations in microelectronics, biology, chemistry, and physics, have significantly improved the performance of many clean-energy technologies and brought them into price parity with conventional power, or provided value-added benefits that justify premium prices.
- **Pressing environmental issues**, notably global climate change, have stepped up pressure on countries, companies, and communities to find more environmentally benign ways to meet the world's growing power needs. The growth of clean-energy technologies is at the top of nearly every government's and multilateral organization's list of solutions to addressing climate change.
- **The rise of the developing world** — including China, India, Latin America, Africa, and Eastern Europe — are prompting new business opportunities. In many cases, businesses and governments in these areas are seeking leapfrog energy technologies that avoid the need for costly power grids and that can be developed at the regional or village levels. The US Agency for International Development estimates that the global market for climate-related technologies — of which clean energy is a significant component — will be valued at US$4 trillion to US$5 trillion over the next twenty years.
- **Strategic Investors**. Investors, while cautious, are warming to the clean-energy marketplace. They include not just venture capitalists and investment banks, but also multinational companies, which are committing billions to clean-energy technologies. For example, last year, Royal Dutch/Shell said it would renew its renewable energy investment program with a further US$500 million to US$1 billion spend earmarked for the next five years. General Motors Corp. bought a significant piece of Quantum Technologies, a hydrogen-storage company that the automaker said would speed up the development of hydrogen fuel cells. BP Amoco, which owns BP Solar, one of the world's largest makers of solar panels, has committed US$500 million over five years to clean-tech development. These so-called strategic investors are helping fuel interest in fuel cells, photovoltaics, microturbines, and the many related systems and components that surround these technologies.
- **Government Commitments**. One of the many factors attracting investors to clean energy are the commitments being made by governments around the world to adopt these technologies. The European Union has committed its member countries to obtain 20% of its electricity needs from renewables by 2010. (Some individual countries have even more ambitious goals.) Japan's government, in a market-development role, has committed significant resources to building out that country's solar photovoltaic industry. Meanwhile, the multinational organizations are working aggressively to bring clean-energy investments

to the developing world. For example, the Global Environment Facility, a joint funding program of the United Nations and The World Bank, has earmarked US$400 million in loans and grants for renewable energy, which is expected to leverage US$2 billion to US$4 billion in projects over the next few years.

- **Venture Capital**. North American equity markets have been fueling much of the growth in the clean-energy sector. For example, venture capital investments in clean-energy technologies have increased more than tenfold over the last five years. While governments and multinational companies are investing heavily in clean-technology R&D, significant capital and market-creation investments are coming from venture capitalists and angel investors, the principal financial engines behind the high-tech revolution of the past two decades.

In the clean-tech field, US investments have grown steadily. In 2000, North American clean-technology companies saw investments totaling more than US$2 billion. Of this total, more than US$1.4 billion came from equity investments in early-stage and follow-on deals, plus more than US$600 million in investments raised via initial public offerings. Clean-energy companies represented the bulk of these investments.

In 2001, investments in clean-energy technologies saw a significant slowdown, reflecting changes in the overall equity markets due to the economic downturn, although there remained much interest in clean energy. Several companies, including H2Gen Innovations, Ocean Power Technologies, PowerLight, RealEnergy, Serveron, and Xantrex, each raised between US$1 million and US$50 million in venture funding from sources as diverse as the California Public Employees' Retirement System (CALPERS), Credit Suisse First Boston, Detroit Edison, the Micro-Generation Fund, and Nth Power.

Clean Edge research shows over the near- to mid-term, clean-energy markets are likely to regain their momentum.

Table 1: Select North American Clean-Energy Equity Investments in 2001

COMPANY	DESCRIPTION	FUNDING (US$ MILLIONS)	INVESTORS
CellTech Power, Inc.	Solid oxide fuel cell (SOFC) developer	$6.5	Arete Ventures, DTE Ventures, Minnesota Power, Nth Power, Zero Stage Capital
H2Gen Innovations	Hydrogen fuel cell appliances	$4.7	Nth Power, Micro-Generation
PowerLight Corp.	Solar PV manufacturer and integrator	$5.4	New Energy Invest Ltd.
RealEnergy Inc.	Energy infrastructure design and management	$50	Arden Realty, CS First Boston, Detroit Edison, GFI Energy Ventures, Global Innovation Partners
Serveron	Energy reliability and monitoring services	$16.5	Cascadia Pacific Management, ECT Merchant Investments, Nth Power, Perseus LLC, Ventures West
Solar Electric Light Co.	Solar energy services and distribution in developing world	$3	New Energy Invest Ltd.

Source: Energy and Environmental Capital Network and Clean Edge, Inc.

CLEAN-ENERGY TRENDS TO WATCH

Clean-tech products and services will be shaped by a variety of trends and forces. The following five trends offer a snapshot of some of the emerging developments we believe offer investors, industry, and policymakers unique opportunities in the near- to mid-term. Also included are select resources and companies to watch for each trend – not a definitive list, by any means, but rather a sampling of the companies and resources we're tracking.

1. THE ENERGY WEB

A marriage of the energy, telecom, and software sectors is working to create a new breed of "smart" appliances, buildings, and vehicles that, in turn, will be connected to a disparate electric web powered by a wide range of energy sources, including renewables and other distributed-generation technologies.

In the "energy web," buildings and vehicles can serve as an energy user or producer at any given time.

In the new "Energy Web," as it has been dubbed, appliances will be integrated with energy-management software that will automatically communicate with its electricity provider. If the "grid" (though it may no longer be called that) gets stressed, it may seamlessly power down select appliances – refrigerators, air-conditioning systems, and others – that don't require always-on power. And rather than turning off an entire neighborhood or business district at a time – á la California's rolling blackouts – the individual appliances will be turned off and on again individually, causing less stress on the entire electric system – and on its customers.

We're already seeing signs of the Energy Web coming online. For example, energy management systems linked to real-time reporting systems already are helping businesses and consumers track and conserve energy. Smart wireless- and telephony-based meters are helping utilities manage costs and share detailed information on consumption patterns for electricity, natural gas, and water with their customers. These devices are enjoying a surge in demand as utilities look for ways to increase efficiencies and offer value-added services in an age of deregulation.

That's only a beginning. With fuel cells and microturbines powering buildings and vehicles, each can serve as an energy user or producer at any given time. So, while vehicles are parked at work or at home – as they are 95% of the time – they could be buying power from the local system or selling back into it. And each device could negotiate in real time with a variety of energy providers for the best rates to buy (or sell) energy at any particular moment.

There are a great many other new products and services that will emanate from the Energy Web – including, no doubt, many that haven't yet been though of, from com-

panies yet to be born. We believe there is a great deal of untapped opportunity for investors to help build the new companies.

Select Companies to Watch

Advanced Energy www.advancedenergy.com

Inari www.inari.com

Intellon www.intellon.com

Silicon Energy www.siliconenergy.com

Sixth Dimension www.sixthdimension.com

Select Resources

The Energy Web — Wired Magazine
www.wired.com/wired/archive/9.07/juice.html

Electric Power Resource Institute — Electricity Technology Roadmap Initiative
www.epri.com/corporate/discover_epri/roadmap/index.html

Micropower: The Next Electrical Era
www.worldwatch.org/pubs/paper151.html

Energy Web: A New Kind of Network
www.bpa.gov/Energy/N/tech/energyweb/index.cfm

Scenarios for a Clean Energy Future www.ornl.gov/ORNL/Energy_Eff/CEF.htm

2. THE HYDROGEN INFRASTRUCTURE

The promise of a hydrogen-powered world has been with us for years, but only recently has that promise begun to be realized in any meaningful way. With the rapid development of hydrogen-powered fuel cells by hundreds of companies, governments, and researchers around the world, energy experts can begin to foresee fuel cells' mass acceptance and use. While there remain many technological, economic, and marketplace hurdles to clear before hydrogen-powered fuel cells achieve mass-market status, their development and commercialization is no longer a scientist's pipe dream.

Picking winners will be no mean feat. There are several systems competing to become the technology of choice for fuel-cell power.

Or an investor's. Today, there are hundreds companies manufacturing or developing fuel cells, or any of the countless components that will be required to integrate fuel cells into vehicles, buildings, and other things. Beyond these manufacturers is an equally large group of companies focusing on building what has come to be called the Hydrogen Infrastructure — the assemblage of products, services, and systems needed to manufacture, store, transport, and deliver hydrogen for use in fuel cells. We believe the development of the Hydrogen Infrastructure represents a significant mid-term opportunity for investors.

Building the Hydrogen Infrastructure will be no small task. At present, there are several systems competing to become the technology of choice for fuel-cell power. They range from more incremental technologies, utilizing gasoline and other readily available fuels to generate hydrogen, to cleaner technologies that have a longer way to go to be fully developed. Some technologies involve building massive new infrastructures, while others piggyback on existing ones. Some technologies are larger, more centralized systems while others adopt more localized, distributed models. Integrating these disparate systems will be one key challenge to building the Hydrogen Infrastructure. Another will be resolving issues of safety, codes, and standards that will allow the Hydrogen Infrastructure to reach its fullest potential.

Picking winners will be no mean feat. There are hundreds of companies manufacturing or developing fuel cells, or any of the countless components that will be required to integrate fuel cells into vehicles, buildings, and other things. Beyond that is an equally large group of companies focusing on building the Hydrogen Infrastructure. Each of their competing technologies is vying for a piece of what will be a vast multibillion-dollar market.

Select Companies to Watch

Ballard Power Systems www.ballard.com

Energy Conversion Devices www.ovonics.com

Millennium Cell www.millenniumcell.com

Nuvera Fuel Cells www.nuvera.com

Powerball Technologies www.powerball.net

Stuart Energy www.stuartenergy.com

Select Resources

California Hydrogen Business Council www.ch2bc.org

HyWeb www.hyweb.de/index-e.html

Hydrogen Fuel Cell Institute www.h2fuelcells.org

Hydrogen Guide www.hydrogenguide.com

International Association for Hydrogen Energy www.iahe.org

3. BRINGING SOLAR TO SCALE

There are significant investment opportunities to back innovative companies offering dramatic breakthroughs in solar's economies of scale.

The vision of electricity from solar cells making a major contribution to the world's energy future is a compelling one. But so far, the vision of a solar future has been only a vision. Today's worldwide solar industry is tiny – capable of manufacturing only about 350 megawatts of solar panels a year. There are fewer than 30 megawatts of grid-connected solar panels installed in the entire U.S.

The mass market for solar electricity has yet to emerge. We believe there are significant investment opportunities to back innovative companies offering dramatic breakthroughs in solar's economies of scale – specifically, the cost of producing solar photovoltaic arrays and of getting them installed and operational on a mass basis.

Economies of scale show great promise for creating the breakthrough to the mass market for solar. To date, the industry has not operated at a large enough scope to create economies of scale, with typical manufacturing plants producing less than 20 MW of solar panels per year. Several studies conclude that the large-scale production of solar panels is feasible using current technology. These studies also conclude that there are significant cost savings for the installation of solar panels through standardization. Finally, these studies conclude that the first large-scale production and installation project for solar panels would reduce the price of solar panels by 50% or more, yielding electricity from solar cells at 7 to 10 cents (US) per kilowatt-hour. This is competitive with the average price of electricity in many markets, and the studies show that there is significant demand for solar electricity at these prices.

Select Companies to Watch

AstroPower www.astropower.com

BP Solar www.bpsolar.com

PowerLight www.powerlight.com

Sharp www.sharp-world.com

Siemens Solar www.siemenssolar.com

Select Resources

American Solar Energy Society www.ases.org

Solar Buzz www.solarbuzz.com

Solar Access www.solaraccess.com

Solar Electric Power Association www.solarelectricpower.org

4. THE MICROTIZATION OF FUEL CELLS

Micro fuel cells demonstrate high potential to replace dry-cell batteries for both consumer and industrial applications.

As recent headlines have demonstrated, the development of fuel cells for buildings and vehicles is well underway. But another, equally exciting and significant market of micro fuel cells for portable electronics is waiting to be tapped. Market opportunities are vast for the type of portable power made possible by micro fuel cells. In addition to cell phone applications, they may also be developed for use in personal digital assistants, laptops, and many other electronic devices. We believe micro fuel cells demonstrate high potential to replace dry-cell batteries for both consumer and industrial applications, creating multi-billion-dollar markets for better, cleaner batteries.

Researchers are harnessing a variety of technologies to produce micro fuel cells. For example, some are applying minifabrication technology to print multiple layers of fuel cell components onto a substrate that will permit low-cost, high-volume production of fuel cells rather than building them by hand. The goal is to produce fuel cells the way that integrated circuits are now manufactured.

Prototypes already are being developed for methanol-powered fuel cells, of similar size and price and half the weight of nickel-cadmium batteries, but with 50 times more energy. The micro cells, which require 1.5 ounces of methanol to operate, are estimated to last at least 20 years, where conventional batteries wear out in about two years. This means phone users can leave their phones on for weeks, and can talk for as much as 100 hours. Another prototype uses ethanol, a cheap, plentiful fuel. As one researcher described it: "I could pull a bottle of good vodka out of a hotel minibar, pour some into a fuel cartridge and place it in the fuel cell."

Select Companies to Watch

Electric Fuel Corporation www.electric-fuel.com

Manhattan Scientifics www.mhtx.com

Medis Technologies www.medistechnologies.com

Motorola www.motorola.com

Samsung www.sait.samsung.co.kr

MTI MicroFuel Cells www.mtimicrofuelcells.com

Select Resources

Eye for Fuel Cells www.eyeforfuelcells.com

The Hydrogen and Fuel Cell Investor www.h2fc.com

MIT Technology Review, "A Fuel Cell in Your Phone"
www.techreview.com/magazine/nov01/voss.asp

***Tomorrow's Energy — Hydrogen, Fuel Cells, and the Prospect for a Cleaner Plant*, by Peter Hoffmann**
www.amazon.com/exec/obidos/ISBN=0262082950/cleanedge-20

5. CARBON NANOTUBES

One of the advantages hydrogen has over other renewable fuels like solar and wind is that it can be stored for use at later time when it is needed. Solar- and wind-powered energy, on the other hand, must generally be used as they are generated. But storing hydrogen is no simple matter. And the varied uses of fuel cells – in vehicles, buildings, and portable devices – require a variety of fuel-storage technologies.

Among the most promising advances in hydrogen storage is carbon nanofiber technology. Nanotubes – tiny, tube-shaped carbon molecules that are molecular cousins of buckminsterfullerenes or "bucky balls" – have an uncanny ability to adsorb and collect hydrogen on their surfaces. Single-walled nanotubes are formed by rolling single-atomic graphite layer into a cylinder. They are extremely small – a bundle of a million nanotubes is about the size of a human hair. Nanotubes make it possible to control materials at the molecular level, providing wide applications in many high-tech areas. They can serve as an ideal cylinder for storing hydrogen, as their diameter is close to that of the hydrogen atom. When the nanotube is heated, hydrogen can be released into a fuel cell.

Nanotubes make it possible to control materials at the molecular level, providing wide applications in many high-tech areas.

One of the critical factors in nanotubes' usefulness as a storage medium is the ratio of stored hydrogen to carbon. According to the US Department of Energy, a carbon material needs to store 6.5% of its own weight in hydrogen to make fuel cells practical in cars – enabling them to travel 300 miles between refueling. To date, researchers have produced nanotube clusters that store more than 4% of their weight in hydrogen. But according to a presentation made at the Nanotube 2001 conference, "Scientists from the National University of Singapore have released figures for nanotubes and nanofibers that can store 10% to20% of their weight in hydrogen."

We believe further developments in nanotubes – as well as other technologies for harnessing nanotechnology to produce and deliver clean energy – represent a significant investment opportunity.

Select Companies to Watch

Carbon Nanotechnologies www.cnanotech.com

Covalent Materials www.covalentmaterials.com

Mitsui www.mitsui.com

NEC Corp. www.nec.com

Nikkiso www.nikkiso.co.jp/english

Select Resources

Foresight Institute www.foresight.org

NanoDot www.nanodot.org

The Nanotube Site www.pa.msu.edu/cmp/csc/nanotube.html

THE ROAD AHEAD

These trends and technologies represent huge opportunities – and challenges – for both investors and innovators. Determining which technologies will be winners in the new-energy economy will require equal parts strategy, knowledge, and luck. It is most likely that there will be more than one set of winners, as different technologies gain acceptance for different applications and markets while others compete head to head for market share. Along the road to building a new clean-energy future will be the usual array of overnight successes, false starts, overhyped failures, and quiet, reliable cash cows. At Clean Edge, we believe savvy and informed investors have much to gain as these new technologies and markets begin to develop and mature.

ABOUT CLEAN EDGE

Clean Edge is a leading market research and consulting firm focused on building clean-tech markets. The company's mission is to help companies and investors understand and profit from the clean-tech revolution. Clean Edge's products and services include strategic consulting; insightful and timely publications, reports, and online resources; conferences and events; and venture and investment-related services. Founded in 2000 by high-tech and green-business entrepreneurs Joel Makower and Ron Pernick, Clean Edge is based in Oakland, California.

To keep abreast of the latest clean-tech developments, track clean-tech stocks, read industry reports, or sign-up for CLEANWATCH, our free twice-monthly newsletter, visit www.cleanedge.com. To contact Clean Edge, e-mail us at info@cleanedge.com or call 510/465-3600.

