CLEAN TECH:

PROFITS AND POTENTIAL

BY JOEL MAKOWER
AND RON PERNICK

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CLEAN EDGE
THE CLEAN-TECH MARKET AUTHORITY

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Joel Makower and Ron Pernick are co-founders and principals of Clean Edge, Inc.

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ABOUT CLEAN EDGE, INC.

Clean Edge, Inc. fills a vital role in the clean-technology sector through a variety of products and services that provide clear, concise, and balanced market research and intelligence. The company's mission is to serve as a catalyst for clean-tech development by helping investors, industry, and society understand and profit from the clean-tech revolution.

Clean Edge™ harnesses the knowledge and expertise of a global network of analysts, researchers, consultants, and professionals. It aggregates, filters, and analyzes clean-tech trends, news, and research and connects investors, companies, and innovators.

Clean Edge focuses on two core audiences at the forefront of clean technology:

- **Investors:** Venture capitalists, investment bankers, angel investors, international development officials, and other key investment professionals.
- **Innovators:** Clean-tech focused entrepreneurs, start-ups, inventors, multinationals, manufacturers, suppliers, distributors, buyers, and marketers.

Products and Services

- **Publications and Reports:** Market research publications and reports; online publishing; and stock tracking and indexing.
- **Consulting:** Multi-client studies; investor due-diligence; business development and opportunity assessment; and marketing communications.
- **Conferences:** Co-sponsored events; venture fairs; and speaker's bureau.

To learn more, visit Clean Edge on the web at www.cleanedge.com or e-mail us at info@cleanedge.com

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CONTENTS

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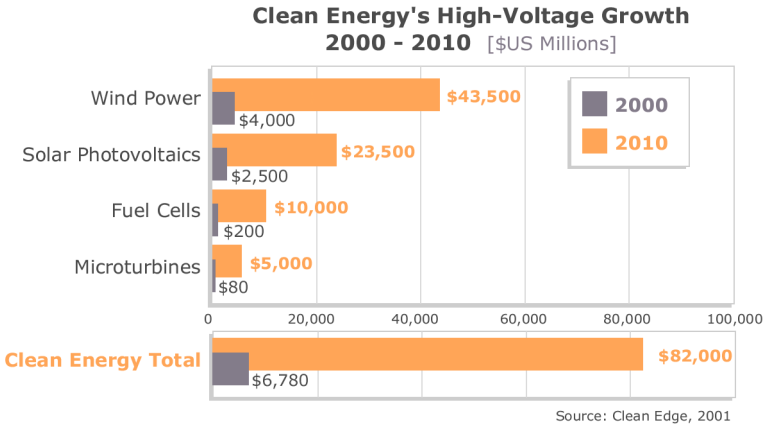
CLEAN TECH: PROFITS AND POTENTIAL

Amid the litany of millennial doom-and-gloom stories—energy price hikes and rolling blackouts, economic slowdown and dot-com meltdowns, and continued controversies over everything from genetics to global warming—there's a genuine bright spot: Clean technologies are booming.

> "I'm interested in making things again. Clean water, transportation, clean power—those are the big markets of the future.
>
> JOHN DOERR, PARTNER, KLEINER PERKINS

For all the hype about the New Economy—the irrationally exuberant world of e-business products and services—a real, sustainable new economy is emerging. It is based on proven markets for essential goods and services, such as clean energy, transportation, water, and materials that embody the emerging principles of industrial ecology, resource productivity, and natural capitalism.

We believe clean technologies are poised for dramatic growth in a manner that will offer significant and tangible economic, environmental, and social benefits. Based on our research, our extensive network, and our analysis of a wide range of research from other credible sources, we conclude that:

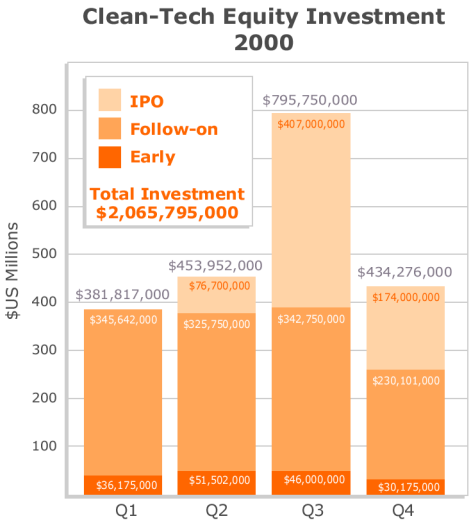


Source: Clean Edge, 2001

- **The markets for clean technologies, while still nascent, will rise significantly.** For example, we estimate the markets for clean energy technologies growing from less than US$7 billion today to US$82 billion by 2010. Some clean technologies, such as wind power, photovoltaics, and fuel cells, will continue to experience double-digit annual growth. However, the growth of clean technologies will be uneven, with some experiencing faster commercial ramp-up than others.

- **The number of companies offering clean-tech goods and services will experience a similar growth curve**, with hundreds of start-ups reminiscent of early markets for e-business, telecom, and wireless technologies. The significant differences that exist between clean-tech and e-biz companies likely will result in fewer boom-and-bust business cycles than were experienced among many high-tech companies.

- **Investment money will pour into clean technology firms at an accelerating rate** as investors, though chastened by the nosedive in technology stocks, view clean tech's attractive growth potential. During 2000, more than US$1.4 billion of equity investments



Source: Energy & Environmental Capital Network, 2001

were made in clean-tech companies by angels and venture capital firms. Adding the money invested in clean-tech firms through initial public offerings, the total escalates to more than US$2 billion. Company research-and-development investments in clean tech will skyrocket, too, with a few companies in each sector leading the way.

"Green technologies are on the verge of becoming one of the next waves in the knowledge economy revolution."

TONY BLAIR
PRIME MINISTER, GREAT BRITAIN

- **Clean technologies stand to provide significant relief to shortages in energy, water, and other natural resources**, while providing a path for both developed and developing countries to address such pressing concerns as greenhouse gas emissions, deforestation, resource scarcity, and air and water pollution.

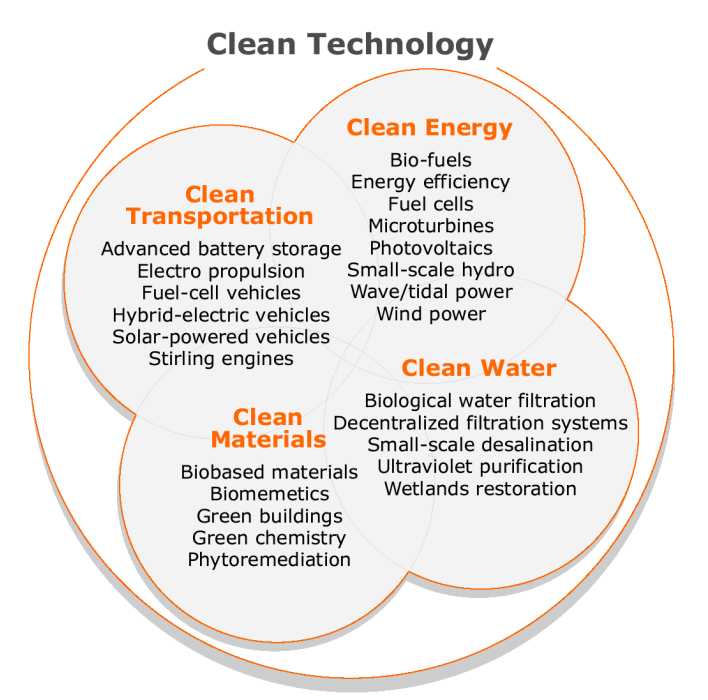
- **Clean technologies will engender a variety of social benefits**, from reduced illness and infant mortality to citizens' improved ability to hold meaningful jobs and raise families. As such, clean tech increasingly will become a cornerstone of the growing global movement toward a more just and sustainable society.

- **The success of clean technologies will depend nearly as much on government investments and policies** as on companies' entrepreneurial and marketing skills. Some countries—in northern Europe, for example, as well as Japan—recognize this and are aggressively promoting clean-tech agendas. Other countries may be forcing clean-tech companies to compete on an uneven playing field through subsidies and policies that favor coal mining, oil drilling, clearcutting, and other "dirty" technologies.

What is Clean Technology?

We define clean technology as a diverse range of products, services, and processes that harness renewable materials and energy sources, dramatically reduce the use of natural resources, and cut or eliminate emissions and wastes. Clean technologies are competitive with, if not superior to, their conventional counterparts. Many also offer significant additional benefits, notably their ability to improve the lives of those in both developed and developing countries.

Because clean tech spans a variety of Standard Industrial Classifications, we have categorized it into four principal domains, describing the nature of the goods and services provided under the clean-tech rubric: energy, transportation, water, and materials. We believe all four domains are undergoing fundamental transformations that will result in profound changes to both the products themselves and the size and nature of their markets. This illustration shows examples of technologies within each domain.



WHY NOW?

Today's clean-tech revolution is the result of a convergence of environmental, technological, economic, and social factors. Among them:

- **Energy uncertainty**, exemplified by electricity shortages in California, has increased demand for "distributed generation," technologies such as microturbines, wind turbines, 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.

- **Technological advances**, including continued innovations in microelectronics, biology, chemistry, and physics, have significantly improved the performance of many clean technologies.

- **Pressing environmental issues**, including global climate change, deforestation, air pollution, and inadequate supplies of clean water, have stepped up pressure to find more environmentally benign ways to meet the needs of a growing world. The concern over climate change in particular has led to new focus in alternative transportation and energy technologies.

- **Changing political winds** have led many government leaders to recognize that future competitiveness is directly linked to being more resource-efficient and less reliant on older, polluting technologies.

- **The sustainable development** imperative, which aims to balance environmental, economic, and social interests as a means of addressing the needs of the world's citizens, has increased the demand for clean, affordable, and resource-efficient technologies in the newly open markets of China, India, Latin America, Africa, and Eastern Europe.

> "We have a basic notion that unless we find a solution for environmental problems, we will not be able to achieve sustainable growth in coming years."
>
> HIROYUKI WATANABE
> MANAGING DIRECTOR, TOYOTA MOTOR CORPORATION

- **Vast new business opportunities** presented by the clean-tech revolution have prompted investors to pour billions into new technologies and the companies that can bring them to market. Forward-thinking entrepreneurs are coming forth with a rapidly expanding array of innovations, accelerating the development of many clean technologies.

CLEAN TECH'S GROWING MARKETS

A picture is emerging, piece by piece, that shows the impressive growth and vast market potential for many clean technologies.

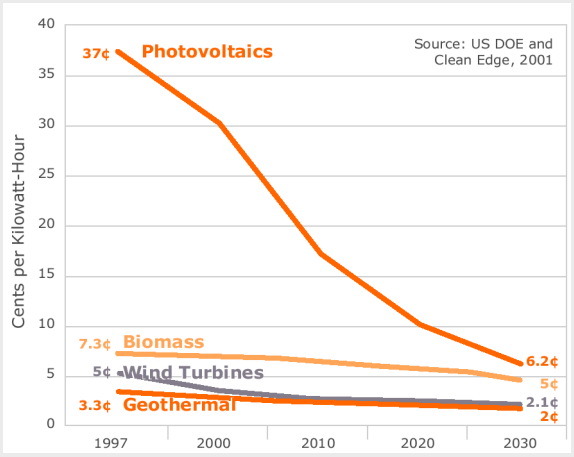
Market Growth for Select Clean Technologies 2000-2010 [$US millions]

Technology	2000 Market	2005 Market [est.]	2010 Market [est.]
Fuel Cells	200	2,500	10,000
Hybrid and Fuel-Cell Vehicles	2,000	10,000	48,000
Microturbines	80	2,000	5,000
Phytoremediation	100	400	1,800
Small-Scale Desalination	100	300	1,000
Solar Photovoltaics	2,500	7,500	23,500
Water Reuse/ Recycling	500	650	1,000
Wind Power	4,000	13,000	43,500

Source: Clean Edge, 2001

The Declining Cost of Renewables

As the chart below shows, the cost of renewable energy sources has been declining steadily in recent years, and will continue to do so through the next few decades. In some cases, such as photovoltaics, costs are expected to plummet, due to improved technology and economies of scale, equaling or beating the 6¢ to 10¢ per kilowatt-hour price of conventional electricity.



Clean Energy

With oil and natural gas prices expected to remain high, and spot shortages anticipated in the US and elsewhere, the forecasts for the global markets for clean-energy technologies are bullish.

Fuel cells, driven in large part by their use in the transportation market, are poised for explosive growth. Currently comprising a market of about US$200 million a year, we estimate the fuel-cell market will grow to US$2.5 billion a year by 2005 and US$10 billion by 2010. As recently as 1996, there was only one fuel-cell company in the US, and only a handful globally. Today, scores of companies around the world have entered the market, including such corporate behemoths as BASF, DuPont, Fuji, General Electric, Honeywell, 3M, Toshiba, and United Technologies. The fall 2000 edition of the *Fuel Cell Directory* bulges with 750 listings of fuel-cell manufacturers, researchers and consultants, suppliers to the fuel-cell industry, utilities, associations, and interested government agencies.

Key Players in the Fuel Cell Market

- ABB
- Avista Labs
- Ballard Power Systems
- Dupont Fuel Cells
- FuelCell Energy
- H Power
- International Fuel Cells
- Plug Power
- Shell Hydrogen
- SatCon Technologies
- Siemens Westinghouse Power

Microturbines, small-scale gas turbine engines that provide onsite power generation for buildings and manufacturing facilities, are seeing surging demand as a result of energy shortages in the western US. While microturbines may be garnering fewer manufacturers than fuel cells, their market is nonetheless significant, expected

Key Players in the Microturbine Market

- ALM Systems
- Capstone Turbine
- Honeywell
- Ingersoll-Rand

"My feeling is that we are at the point in time where the personal computer was in the late '70s. Over the next ten years, if things go well, there's going to be a revolutionary change in the way that we obtain power."

CAMERON "MAC" MOORE
DIRECTOR OF BUSINESS AND UTILITY MARKETS, BP SOLAR

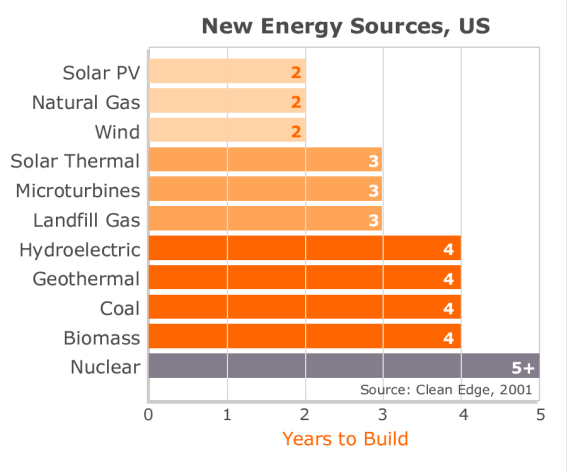
to surge from US$80 million today to US$2 billion by 2005 and US$5 billion by 2010. One reason: microturbines, at least in the short term, offer more immediate applications than most other alternative energy resources. They can serve as back-up power for companies with no tolerance for downtime; can utilize the heat created during electricity generation to make steam for heating space or water; can be used in remote areas; and can operate on any of a number of fuels, including biofuels, derived from plants and waste cooking oils, among other things.

> "We believe that we can eliminate most of our dependence on oil by 2030."
>
> HJALMAR ÁRNASON
> CHAIRMAN ICELANDIC GOVERNMENT'S COMMITTEE FOR ALTERNATIVE FUEL

Photovoltaics—converting sunlight into electricity—is another shining example of a technology on the rise. Solar power's cost is dropping, the result of improved economies of scale as the industry grows. Also pushing down costs are new materials that improve the efficiency at which solar cells convert sunlight into energy.

Bringing New Energy Sources Online: How Fast?

How quickly can countries and regions facing energy shortages build new capacity? Clean-energy generation facilities like solar, wind, and hydroelectric can be brought online much more quickly than coal, nuclear, and other fossil-fuel plants. While a nuclear reactor can, in theory, be brought online in as little as two years, in the US, no new nuclear plants have been approved since the Three-Mile Island disaster of 1979. The chart below shows the estimated time needed to bring a 10-megawatt commercial power plant online.



Countries' Commitments to Renewables

Several national governments have committed themselves to embracing renewable energy. Below is a summary of some of those commitments. The United States, which currently gets about 7.5% of its energy from geothermal, solar, and wind sources, is among the countries that has not set a formal national renewable-energy goal.

Country	Commitment	Country	Commitment
China	2% of total energy consumption from renewables by 2015.	**Iceland**	Virtually all energy from hydrogen sources by 2030.
Denmark	13% of primary energy from wind, solar, and biomass by 2005, 35% by 2030.	**Japan**	3% of its energy supply from renewables by 2010.
European Union	20% of all electricity from renewable sources by 2010.	**Netherlands**	10% of total energy supply from renewables by 2020.
France	21% of all electricity from renewable sources by 2010.	**United Kingdom**	10% of total energy supply from renewables by 2010.
Germany	10% of total energy supply from renewables by 2010.		

Source: Clean Edge, 2001

Key Players in the Photovoltaic Market

- AstroPower
- BP Solar
- Evergreen Solar
- Kyocera Solar
- Sharp
- Solec International
- Shell Renewables
- Siemens Solar Industries
- Solarworld
- Sunways AG Photovoltaics

Innovation is being pushed by Japanese firms such as Sanyo and Kyocera, thanks to subsidies from the Japanese government, helping drive down the price per kilowatt-hour of photovoltaic-produced energy.

Worldwide, solar sales have grown six-fold since 1996 to US$2.5 billion, and should rise to US$7.5 billion by 2005 and US$23.5 billion by 2010, as solar becomes cheap enough to compete with other energy sources without government tax breaks and subsidies. In the developing world, where more than a billion people lack a connection to a central power grid, solar already is competitive with other energy sources.

"Sustainable growth is about ensuring a better quality of life for everyone, now and for generations to come. But it is also about business success, market growth, shareholder value and innovation."

CHARLES O. HOLLIDAY, JR.
CHAIRMAN AND CEO, DUPONT

"There's no cheaper, cleaner power than power you don't have to produce."

GARY ZARKER
SEATTLE CITY LIGHT

The Rebirth of Energy Efficiency

Growing concern over energy consumption and climate change have helped spawn a US$2.4 billion market for energy-efficient products in the US alone, and billions more in energy-efficient building design and construction techniques. In less-developed countries, where inefficiency reigns supreme, the markets are even larger. For example, the potential market for energy efficiency in Central and Eastern Europe and the former Soviet Union is at least US$20 billion for just the industrial sector, and could be US$50 billion to US$60 billion overall.

The table below shows that efficiency represents the second-largest "source" of energy in the US: The amount of energy saved in one year through efficiency is greater than the energy supplied by coal, natural gas, nuclear, and renewables.

US Energy Sources, 1999	
Petroleum	41 quadrillion BTUs (quads)
Energy Efficiency	**27 quads**
Coal	22 quads
Natural Gas	19 quads
Nuclear	8 quads
Hydro	4 quads
Geothermal	0.4 quads
Solar and Wind	0.1 quads

Source: US DOE, Calculated from data in "Renewable Energy: Sources for Fuels and Electricity," Laurie Burnham, ed. (Island Press, 1993), and additional Clean Edge research, 2001.

Solving California's Crisis

Can clean technology rescue California? An examination of energy-efficiency and renewable-energy options suggests that the answer is yes—with room to spare.

The role of efficiency and renewables in filling the gap in the state's energy grid has gone relatively unnoticed amid the clamor for ever-greater supplies of electricity. But their role can provide the critical difference in filling the gap between energy supply and demand without having to build new fossil-fuel or nuclear energy plants. And since California's energy problems are a sign of things to come—not just in California, but throughout the US and beyond—the lessons learned in the Golden State could be critical to solving future energy shortfalls.

Currently, California requires roughly 61,000 megawatts (MW) of power-generating capacity during periods of peak demand. By 2010, that number is projected to grow to just over 72,000 MW. During recent rolling blackouts, the average daily shortfall in the state's energy supply was roughly 5,000 MW.

Here are just a few clean-tech solutions to the California energy crisis:

Solar energy: If photovoltaic collectors were situated on just one-tenth of the available rooftops, parking lots, and open land near transmission lines, solar energy could produce 6,800 MW of power.

Wind energy: California could conservatively install 5,000 MW of wind capacity. Electricity from large new wind farms being built in the Western US will be generated at less than 2.5 cents per kilowatt-hour, a record-breaking low, establishing wind energy as a cost-competitive, emissions-free source of electricity.

Exit signs: California buildings—office buildings, factories, and other facilities—use 12 million to 13 million exit signs at an average power consumption of 40 watts each. New, highly efficient models use as little as one-fifth of a watt. By installing these devices, the state's power consumption could be cut by up to 500 MW and the investment could pay for itself in as little as 7 months.

Building retrofits: The North American Electric Reliability Council estimates the US electricity bill could be cut by more than 60,000 MW through just six measures: replacing and updating older residential cooling systems, residential cooling system tune-up and repairs, installing high-efficiency commercial air conditioning HVAC systems, conducting commercial building tune-ups and maintenance, installing commercial lighting retrofits, and redesigning commercial lighting. California's share of that bounty would be nearly 7,500 MW.

Wind power growth is expected to triple over the next five years, to nearly US$13 billion by 2005, emerging as the front-runner in the alternative-energy race. The gale-force growth is due in large part to wind energy's cost competitiveness with fossil fuels in many markets. The cost of producing electricity from wind energy has declined by more than 80%, from about 38 cents per kilowatt-hour in the early 1980s to a current range of 3 to 6 cents. In the US, costs will drop to a record low of 2.5 cents per kilowatt-hour for the 300 MW Stateline wind farm being developed along the Oregon-Washington border. Wind-energy growth is expected to rise around the world: China is likely to increase its wind-power installations sevenfold between now and 2006, while Germany's capacity will nearly triple.

Key Players in the Wind Power Market

- British Energy
- Électricité de France
- Enercon
- Energias Eolicas Europeas
- Enron Wind Corp.
- Gamesa
- Lagerwey
- NEG Micon
- Powergen Renewables
- Vestas

> "We are witnessing an historic shift from to oil to gas to renewable forms of energy, and a growing business commitment to sustainable development."
>
> JEROEN VAN DER VEER
> MANAGING DIRECTOR, ROYAL DUTCH SHELL GROUP

Clean Transportation

With the world's major automakers gearing up to market hybrid-electric and fuel-cell vehicles, the transportation sector is being transformed. Most experts acknowledge that the days of the internal-combustion engine are numbered, and that new, clean technologies will become mainstream within two decades.

It's not just automobiles. Hybrid-electric and fuel-cell buses already are in production, and makers of everything from ships to trains are developing technologies that radically improve fuel-efficiency and polluting emissions. Many of these innovations involve improvements of existing technologies, such as more efficient designs for existing diesel engines. Other technologies represent radical changes from conventional internal-combustion engines powered by gasoline and diesel fuels.

Key Players in the Clean Transportation Market

- Major auto makers (see table)
- BAE Systems Controls
- Cummins Engine
- Enova
- ExxonMobil
- Hypercar, Inc.
- Shell Hydrogen

"We need a second revolution. Our goal has to be nothing less than an emission-free vehicle that is built in clean plants, which actively contribute to the environment. And it can happen within my lifetime—hopefully within my working lifetime."

BILL FORD
CHAIRMAN, FORD MOTOR CO.

The market for so-called "clean" vehicles, including cars, buses, and trucks, will grow from about US$2 billion today to US$10 billion by 2005 and US$48 billion by 2010.

But these numbers may be misleading. Over time, the distinctions between alternative-fueled vehicles and conventional vehicles will fade, as all cars, trucks, and buses adopt characteristics of today's "clean" vehicles. That could place today's market forecasts on the low side. Indeed, the market for cleaner (read: better) vehicles may turn out to be nearly as large as the vehicle market itself.

Clean Cars: Into the Fast Lane

For years, consumers, environmentalists, and others have pressed the world's auto makers to produce radically different cars, ones that rely on little or no petroleum and produce few if any emissions. Over the next decade, that dream will become reality as major car companies introduce hybrid-electric, fuel-cell, and other clean-vehicle technologies.

Will the public buy them, or will these cars suffer the fate of so many other "green" products that failed to find mass markets? Given the multi-billion-dollar investments being made by major auto makers — often in partnership with oil giants — clean cars seem destined to reach the mainstream. As the table below shows, many of the world's largest car companies will introduce new-generation vehicles in 2003 and 2004, though it could take several years for them to become widely available.

Bringing Clean Cars to the US Market

	Target Delivery Dates	
	Hybrids	**Fuel Cells**
DaimlerChrysler	2003	2004
Ford	2003	2004
General Motors	2004	2004
Honda	2000	2003
Mazda		2005
Mercedes		2004
Mitsubishi		2004
Peugeot-Citroen	2004	2010
Toyota	2000	2003

Source: Clean Edge, 2001

Clean Water

The need for clean, potable water sources is increasing quickly, as demand outstrips supply in a growing number of regions. A combination of political, public health, and climatic trends increasingly will force water to the front lines of public concern in the coming years.

> "Nature has been cleansing water for millions of years, so we figure it's got the process figured out pretty well."
>
> HALFORD HOUSE
> UNIVERSITY OF NORTH CAROLINA WATER-QUALITY SPECIALIST

Water problems are very different in the developed and developing worlds. In the developed world, water infrastructures are being stretched to the breaking point. In the US alone, as much as US$1 trillion will be needed over the next 20 years to upgrade aging water systems. Currently, there is a US$23 billion annual gap in spending plans and available funds.

Meanwhile, some 2.4 billion people in developing countries lack basic sanitation; more than a billion lack access to clean water. The world's poor pay more than the rich for water—up to a fifth of household incomes—but are at greater risk from water-borne illnesses. Some 3.4 million people die each year from water-related diseases, according to the World Health Organization.

Key Players in the Clean Water Market

- American Water Works Co.
- Hydromatic UK
- Ionics
- Ogden Corp.

The investment needs are great: China alone plans to spend nearly US$50 billion on water projects between now and 2005. Scientists believe climate change will exacerbate water shortages in many parts of the world. According to the US Central Intelligence Agency, water scarcity in the Middle East, Africa, South Asia, and China presents the potential for armed conflicts.

> "Lack of water resources is a serious limitation on the economic and social development of our country."
>
> ZHU RONGJI
> PREMIER, CHINA

Water innovators are looking at new technologies to increase clean-water supplies at lower cost, with fewer resources, and in more environmentally preferable ways. Many of these are smaller-scale, distributed technologies, more suited to households, villages, or buildings than to large metropolises. Two examples:

- **Biological water filtration systems** are being designed to provide fresh water to office buildings and other facilities by mimicking nature's processes. For example, in North Carolina, a constructed wetland purifies 1,200 gallons of sewer water daily from the 60 employees who work in a nearby building. The system uses soil, plants, and microscopic organisms to filter and treat the wastewater.
- **Water reuse and recycling** is growing around the world, using increasingly sophisticated technical, marketing, and financing models. Total water reuse in the US is growing by 30% a year to more than 1.2 billion gallons a day, representing a roughly US$500 million market.

Clean Materials

The search for cleaner industrial processes extends to the vast world of materials—the substances that shape our homes, buildings, clothing, automobiles, appliances, and many other things. The goal: materials that take no substances from the earth faster than they can be replaced by natural systems, and put no substances into the air, water, or soil faster than they can be absorbed by nature.

From that ideal has come a vast array of new products and materials. Relatively few achieve this zero-impact goal, but many greatly reduce the resources used to create them or the unmanageable wastes they generate. In some cases, these clean materials themselves harness nature's services to clean up past environmental damage.

> "All designers of human systems can learn much from the natural world, but nature in her wealth has not been effectively consulted as a source of information, inspiration, and innovation."
>
> JANINE M. BENYUS
> AUTHOR, BIOMIMICRY: INNOVATION INSPIRED BY NATURE

Most of these materials and technologies currently represent relatively tiny markets. But each is poised to grow in ways that once seemed unimaginable, potentially garnering a significant piece of several major industrial sectors. Two examples:

- **Biobased products**—goods and materials made from plant matter—have potential to give productive life to millions of tons of agricultural waste that currently is being burned or landfilled. As alternatives to petroleum- or wood-fiber products, they can help reduce greenhouse gas emissions while saving trees and oil for purposes for which there are not yet substitutes. Many biobased products can help reduce emissions of greenhouse gases. Some companies are betting big on the future of the biobased marketplace. Cargill and Dow, for example, are investing more than US$300 million in Cargill Dow Polymers, the first major company to offer a family of polymers derived entirely from plant matter.

- **Phytoremediation**—a process in which plants and other organisms are used to clean up polluted soil and water—is emerging from the lab with the promise of becoming a significant market force. An arsenal of more than 400 species of plants, fungi, and bacteria are being found to effectively neutralize molecules of everything from arsenic to zinc. Researchers have found uranium-loving sunflowers, clovers that soak up oil, ferns that absorb arsenic, mustard plants that consume lead, and poplar trees that treat solvents. While not a panacea for every pollutant, phytoremediation stands to make a significant dent in the estimated US$700 billion needed to decontaminate thousands of toxic factories, military bases, farms, landfills, sewage plants, and other facilities in the US alone. The market remains small—less than US$100 million—but we estimate the market to grow more than 30% annually to US$400 million by 2005 and US$1.8 billion by 2010.

Key Players in the Clean Materials Market

- Cargill
- Dupont
- Edenspace Systems
- Novozymes
- Phytokinetics
- World Energy Alternatives

FOLLOWING THE MONEY

The money trail that drives clean technology leads in a myriad of directions: to entrepreneurs, angel investors, venture capitalists, investment banks, mutual funds, multinational corporations, small businesses, nongovernmental organizations, and government agencies around the globe. Below are some examples of private-sector investments in clean technology.

Where the Money Goes

The table below shows equity investments made in US clean-tech companies during 2000. "Early money" represents investments in early-stage start-ups; "follow-on" money is that invested in existing firms for expansion and product roll-out; and IPOs represent money raised on the open market during firms' initial public offerings.

	Q1 2000	Q2 2000	Q3 2000	Q4 2000	TOTAL
Early stage	36,175,000	51,502,000	46,000,000	30,175,000	163,852,000
Follow-on	345,642,000	325,750,000	342,750,000	230,101,000	1,244,243,000
IPOs	0	76,700,000	407,000,000	174,000,000	657,700,000
TOTAL	381,817,000	453,952,000	795,750,000	434,276,000	2,065,795,000

Source: Energy & Environmental Capital Network, 2001

While governments and multinational companies are investing heavily in clean technology, significant investments also 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, clean technology saw investments of $US1.4 billion in early-stage and growing companies, plus more than US$600 million in investments in initial public offerings.

Big Oil's Clean-Tech Plays

Several of the major oil companies have made significant investments in clean-energy technologies, including fuel cells, solar energy, and wind power. Here are some examples:

Company	Clean-Tech Play
BP Amoco	Owns BP Solar—the world's largest maker of solar panels—has committed $500 million over five years to clean-tech development, and has adopted the tagline "Beyond Petroleum."
ExxonMobil	Partnered with General Motors and Toyota to design a system that extracts hydrogen from gasoline to run a fuel cell.
Royal Dutch/ Shell Group	Investing $500 million in renewable energy, including biomass, solar, and wind power, and has launched Shell Hydrogen and Shell Renewables business units.
Texaco	Created Texaco Ovonic Fuel Cell, a partnership with Energy Conversion Devices, to commercialize fuel cells.

Source: Clean Edge, 2001

Five Largest Private-Equity Clean-Tech Investments [by Round], 2000 [$US millions]

Company	Amt.	Funders
Capstone Turbine	**$125**	Alliant Energy, Canaan Partners, Enertech Capital Partners, Hydro-Quebec Capitech, Nth Power Technologies, Sevin Rosen Funds
Greenmountain.com	**$100**	BP Amoco and others
Global Thermelectric	**$87**	Goepel McDermid Inc., Sprott Securities Inc., TD Securities
Essential.com	**$75**	Amerindo Investment Advisors, Bessemer Venture Partners, Brand Equity Ventures, Catterton Partners, Comdisco Venture Group, Enertech Capital Partners, Mellon Ventures, Rare Ventures, Sycamore Ventures
Proton Energy Systems	**$50**	Arete Ventures, Beacon Partners Inc., Chase Capital Partners, Connecticut Innovations, Lehman Brothers, Nth Power Technologies, Perseus LLC, Solstice Capital

Source: Energy & Environmental Capital Network, 2001

Over the past year, more than a dozen venture firms have targeted clean technology, and the value of publicly traded clean-tech companies has increased. Overall, the total combined market capitalization of 25 leading clean-tech companies traded on US exchanges stood at just over $16.5 billion on April 16, 2001. Three firms—American Water Works, Ballard Power, and Capstone Turbine—each had market capitalizations greater than US$2 billion.

Select Clean-Energy Venture Firms

Venture capital investment in distributed energy has increased more than tenfold in the past five years, reaching more than $1 billion in 2000. Here is a sampling of venture funds and their holdings.

Name	Investments	Sample Holdings
Advent International	An international private equity firm, with more than US$4.5 billion under management. It set up a fund in 1995 focused on energy technologies.	Active Power, AstroPower, Ballard Power Systems, Bolder Technologies, Superconductivity, Thai Storage Battery
Arete Corp.	Its pioneering Micro-Generation Technology Fund was established in 1997. To date, it has invested in 17 companies with typical investments ranging from US$500,000 to US$3 million.	American Superconductor, Astropower, Ballard Power Systems, Beacon Power, Bowman Power, Capstone Turbine, Cell-Tech Power, Encorp, Evergreen Solar, Hydrogenics, Metallic Power, Northern Power Systems, Powerzyme, Proton Energy Systems
Energy Ventures Group	A boutique energy investment firm with a focus on emerging technologies in the energy services sector.	Silicon Energy, Sixth Dimension
Merrill Lynch New Energy Technology	One of the earliest non-venture-capital investors in the alternative energy and energy technology sectors. The fund was fully subscribed at £200 million — about US$287 million.	AstroPower, Energy Conversion Devices, Gamesa, NEG-Micon, Vestas Wind
Nth Power	Has closed two funds focused on clean energy—the first at US$63 million, the second at US$120 million. It invests anywhere from US$500,000 to US$5 million per holding.	Allconnect.com, Capstone, EPC, Evergreen Solar, INARI, Metallic Power, NanoGram, Proton Energy Systems, Silicon Energy, Water Management Services
Perseus	A merchant bank and private-equity fund management company, it has made a number of significant investments in energy technology companies, focusing on companies addressing power quality and reliability and distributed generation.	Beacon Power, Nexus Energy, Powercell, Proton Energy

Source: Clean Edge, 2001

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The future of clean technologies, however promising, won't come easily or cheaply. A myriad of challenges could derail one or more technologies, or at least slow their development and implementation. Among the wildcards:

- **Government support** will be critical for the advancement of clean technologies. To succeed, clean tech will need adequate and reliable research-and-development budgets as well as incentive systems to promote and support clean-tech purchases by businesses and consumers alike. Toward that end, governments must identify and, as much as possible, eliminate subsidies that give an unfair advantage to conventional fuels and technologies that compete with new, cleaner technologies.
- **Robust economies** will be a vital factor in spurring clean-tech investments. Recessions or stock-market plunges could retard or curtail private-sector investments at a time when access to capital is critical to success.
- **Industry resistance**—through lobbying or policies that stifle competition—could deal a blow to some companies and technologies. For example, if energy utilities make it difficult for customers to generate their own power, and to sell excess power back into the grid, markets for alternative energy technologies could slow significantly.
- **Standards** will play an important role in ensuring the growth and market acceptance of some clean technologies. For example, sales of alternative building products made from plant-based material could languish without changes in building codes that allow them to substitute for conventional products like wood or drywall.
- **Infrastructure changes** will be necessary for some technologies to take off. For example, the forthcoming generation of fuel-cell vehicles could require a system in which hydrogen-fueling stations become as prevalent as gas pumps.
- **Customer acceptance** of new technologies will be an obviously crucial factor in determining which technologies succeed. Their acceptance will no doubt require copious quantities of education to explain the products' benefits—to the buyer as well as to the environment and society. Companies, government agencies, and others will need to play a major role in promoting the reliability, performance, and safety of clean technologies to an often-skeptical and reluctant marketplace.
- **Activist pressures** will likely play a key role in keeping the heat on companies, governments, and others to develop and promote clean technologies. Activists also can play a role in educating their constituencies about the new technologies, and in watch-dogging companies and politicians to ensure that their promises are kept and their marketing campaigns are truthful.

Beyond these are a host of unforeseen obstacles and opportunities, ranging from regional conflicts and other events that cause perturbations in energy supplies, to unusual weather cycles that raise increased concern over climate change, to environmental catastrophes that accelerate public interest in clean technologies, to any of a number of unanticipated events and unintended consequences that cause the fortunes of clean technologies to rise or fall.

Up-and-Coming Clean Technologies

Researchers and product developers in agriculture, chemicals, construction, energy, forestry, household goods, petroleum, textiles, and many other sectors will continue to develop new, cleaner technologies that meet human needs while reducing environmental impacts—and creating vast investment and business opportunities. Also on the horizon are entirely new disciplines, such as the emerging field of biomemetics, which takes inspiration from nature's models to solve human problems and needs.

Here are a few examples of ideas and technologies we are following:

Technology	Essentials	Status
Car-powered homes	Fuel-cell vehicles may one day supply electricity to the power grid, serving as generators when they are not on the road—which is 90% of the time for most vehicles. If proven cost-effective, vehicles could generate enough electricity to reduce the requirement for global central station generation capacity by up to 20% by the year 2050.	The Electric Power Research Institute, an industry-sponsored group, is seeking partners from the energy, utility, and automobile sectors to develop standards and systems. Prototypes are 5-7 years away.
Mushrooms that clean toxic wastes	A process called mycoremediation uses mycelium, the vegetative part of a fungus, to break down contaminants. The process is being tested on such contaminants as petroleum, fertilizers, pesticides, explosives, and a wide assortment of agricultural, medical, and industrial wastes. In field applications, nature's microbes interact with the fungi to completely break down contaminants to carbon dioxide and water.	Scientists at Battelle Laboratories have conducted successful tests with a Washington company, Fungi Perfecti, using Oyster mushrooms to break down heavy oil. Commercialization could begin by 2003.
Off-shore wind power	The windy oceans are a perfect place to set up wind generators, where large turbines won't spoil the view. The potential of the ocean winds is substantial. Example: The UK, one of the windiest countries in Europe, has enough offshore wind to supply three times the country's total electricity requirements, according to government figures.	Offshore wind is taking off in Northern Europe, where Denmark is building a series of large-scale wind farms at sea to generate half the country's power. The UK government is including offshore wind power as part of its goal to produce 10% of its electricity from renewables by 2010.
Trash-powered fuel cells	Fuel cells can run on a variety of fuels, and solid waste produces gases when it decays, so a fuel cell that runs on waste-generated gases makes sense. Prototypes have been developed that harness both methane and hydrogen from conventional waste. A pound of garbage, for example, will produce about 7 cubic feet of hydrogen and an average fuel-cell car driving 11,000 miles per year uses about 109 cubic feet of hydrogen per day—about 16 pounds' worth of trash.	In the US, Portland, Ore., a methane-powered fuel cell at the Columbia Wastewater Treatment Plant provides power to run the plant. Startech Environmental has unveiled a commercially sized system for extracting hydrogen from solid waste for fuel cells. Each device can supply enough hydrogen per day to power about 400 fuel-cell cars.
Wave and tidal power	Ocean waves and tides can be harnessed to produce a tremendous amount of energy. For example, when waves hit a device called an oscillating water column, the air inside is compressed and forced through air turbines to create electricity. Tidal power stations can stretch over deltas, estuaries, beaches, or other places affected by tides. Some tidal power stations can produce 320 megawatts of electricity.	Wave-power stations are mostly experimental, though one is already in use in Norway, creating 500 kilowatts of electricity. Tidal-power stations are being used in Canada, France, Russia, and China.

Source: Clean Edge, 2001

The opportunities and uncertainties will make the coming decade a critical period for clean technology. Much like the Internet revolution, there will be winners and losers, and more than a little carnage among companies and entrepreneurs competing for a slice of the clean-tech pie. But there's a great deal of evidence to suggest that clean technology will engender a more sustainable and highly profitable era—for business, the planet, and all of its denizens.