

## Introduction

# THE CLEAN-TECH OPPORTUNITY

In New York City, hiply dressed residents of the Solaire, a luxury apartment building in lower Manhattan, head home after a day of office work and mocha grandes. They step into a Cesar Pelli & Associates–designed “green building” that uses 35% less electricity and 50% less water than comparable structures, thanks to solar photovoltaic panels, energy efficiency, and recycling.

Half a world away, a group of engineers from New Hampshire is testing water-purification devices in a small village in Bangladesh. The mobile devices, dubbed Slingshots, are a product from inventor Dean Kamen of DEKA Research and Development Corp., best known as the creator of the Segway scooter. Powered by a small amount of biofuel such as wood or cow manure, the Slingshot harnesses its own waste heat to use 50 times less energy than traditional purification systems.

In another small town—Elkin, North Carolina—textile mill workers are turning out fibers for carpeting from Atlanta-based Interface Engineering, one of the world’s largest suppliers of commercial flooring materials. The Terratex brand fabric is a combination of 100% recycled polyester and so-called bio-based fibers, derived from corn, rice, and beet plants. Some of the carpet fibers are not only recyclable but also fully compostable and biodegradable.

Welcome to the future—today. Following on the heels of the computer, Internet, and biotech revolutions, “clean tech” is bringing unprecedented

opportunities for wealth creation, high-growth career development, and innovative solutions to a range of global problems. It is becoming the cornerstone of corporate, investment, and government strategies to profit in the next decade and to guarantee economic competitiveness for years to come.

At a time when the U.S. economy sputters in fits and starts and faces unprecedented challenges from high energy prices, depleted natural resources, volatile sources of foreign oil, record deficits, and unprecedented environmental and security challenges, clean tech offers the promise to be the next big engine of business and economic growth. Companies, investors, entrepreneurs, job seekers, and governments have a choice to either embrace and lead in this brave new world of clean-tech innovation or risk falling behind a host of competitors.

At stake: trillions of dollars in economic opportunity and prosperity for the companies and individuals at the forefront of this next great growth and investment opportunity.

## WHAT IS THE CLEAN TECH REVOLUTION?

For most people the concept of clean technology, or clean tech, is relatively new. *Clean tech* refers to any product, service, or process that delivers value using limited or zero nonrenewable resources and/or creates significantly less waste than conventional offerings. Clean technology comprises a diverse range of products and services, from solar power systems to hybrid electric vehicles (HEVs), that

- Harness renewable materials and energy sources or reduce the use of natural resources by using them more efficiently and productively
- Cut or eliminate pollution and toxic wastes
- Deliver equal or superior performance compared with conventional offerings
- Provide investors, companies, and customers with the promise of increased returns, reduced costs, and lower prices
- Create quality jobs in management, production, and deployment

Clean tech covers four main sectors: energy, transportation, water, and materials. It includes relatively well-known technologies such as solar photovoltaics, wind power, biofuels, bio-based plastics, advanced lithium-ion batteries, and large-scale reverse-osmosis water desalination. It also includes such emerging technologies as tidal power, silicon-based fuel cells, distributed hydrogen generation, plug-in hybrid vehicles, and nano-technology-based materials.

In the 1970s, clean tech was considered “alternative,” the province of back-to-the-land lifestyle advocates, altruistic environmentalists, and lab scientists on research grants—and for good reason: It was in an early stage of development, it was too expensive, it didn’t have widespread political support, and very few large, established companies were embracing the sector. Even at the start of the twenty-first century, the term *clean tech* wasn’t yet in the financial or business community’s lexicon. If you had done a Web search on *clean technology* or *clean tech* in 2000, you’d have received only a few relevant results. If you did a similar Web search on the topic today, you’d find more than 500,000 relevant hits, reflecting today’s reality—clean technology is everywhere.

Throughout the world, in trends large and small, we’re seeing the beginning of a revolution that is changing the places where we live and work, the products we manufacture and purchase, and the development plans of cities, regional governments, and nations around the globe. One need look no further than the daily headlines to see clean tech taking hold. Portland, Oregon, recently became the first city in the United States to require all gasoline sold within city limits to contain at least 10% ethanol. California passed landmark legislation to cap and reduce greenhouse gas (GHG) emissions and to install nearly 1 million solar roofs over the next decade. Gas-guzzling sport utility vehicle (SUV) proprietor Ford has seen its fortunes plummet as those of hybrid-leader Toyota rise. Entrepreneurs have raised venture capital (VC) to develop everything from a high-performance, battery-powered, \$92,000 electric sports car to solar cells based on nanotechnology.

The revolution is not coming; it’s here today. Consider these facts:

- **State mandates in the United States.** More than half of the American people live in states that have mandated that their utilities generate a

specified percentage of electricity (in many cases up to 20% or 25%) from renewable sources such as solar, wind, biomass, and geothermal by a specific target year. Two recent states to join the club, Colorado and Washington, did so by 2004 and 2006 ballot measures that each state's voters approved by comfortable margins.

- **Leadership in the European Union.** Wind farms in Denmark, many of them offshore, now generate about 20% of the nation's electricity, proving many doubters wrong about the viability of clean, renewable energy. Germany and Spain rank first and second, respectively, in world wind-power production, creating thousands of jobs in the process.
- **Clean power options.** Hundreds of investor-owned utilities, municipal utilities, and electric cooperatives in every region of the United States offer the option of green power to customers who can choose to receive electricity from renewable sources. While most of these utilities charge a small green surcharge, that charge is sometimes locked in for a fixed period, providing a hedge against spikes in the price of natural gas. In some regions, green-power customers have at times seen their electric rates drop below those of their neighbors who are paying for conventional power.
- **A solar boom.** The solar PV (photovoltaic) industry reached more than 1 gigawatt (GW, or 1,000 megawatts [MW]) of total manufacturing output in 2004, approximately 1.5 GW in 2005, and more than 2 GW in 2006, making the solar manufacturing and installation industry worth nearly \$16 billion. And it is projected to continue to expand by more than 30% each year for the foreseeable future. Sharp, the leading manufacturer of solar PV modules, believes in a bright future for the technology. The company has expanded its manufacturing capacity from 54 MW in 2000 to a planned 710 MW in 2007.
- **A hybrid takeoff.** Since 2003, hybrid cars have gone from a tiny speck on the automotive landscape to one of the U.S. vehicle market's fastest-growing segments. Toyota doubled its flagship hybrid car's allocation in North America in 2005, to 100,000, and started building hybrids on U.S. assembly lines in 2006. By the end of 2006 there were some 15 hybrid models on showroom floors, including hybrid models for such popular vehicles as the Honda Civic and Accord and the Toyota Camry.

- **Clean extreme makeover.** Since 2000, more than 730 buildings comprising 5% of all new commercial structures in the United States have been certified as green buildings by the U.S. Green Building Council, and nearly 5,800 more are in the pipeline. For example, Ford's 600-acre Rouge Factory complex in Dearborn, Michigan, the world's largest integrated industrial facility when it was completed by Henry Ford in 1928, has undergone a complete "greening." Ford workers assemble trucks under a 10-acre roof with grasses and plants growing on it; the insulation cuts energy costs by nearly 10%.
- **Bio big business.** Bio-based materials are moving from the organic food co-op to the shelves of major chains such as Wal-Mart and Sam's Club. Cargill, via its NatureWorks unit, is manufacturing bio-based materials using renewable resources such as maize instead of petrochemicals. The material uses up to 50% less energy to produce and is compostable. DuPont has also been aggressively pursuing the biopolymers market, launching a new manufacturing facility in 2007 to produce a patented biomaterial based on fermented and purified sugars. Agribusiness giant Archer Daniels Midland (ADM) is building a plant in Clinton, Iowa, that will produce 45,000 tons of natural, corn-based plastics annually after it opens in 2008.

The list goes on and on.

## WHAT IS DRIVING THE REVOLUTION?

So how did clean tech go from the stuff of back-to-the-earth utopian dreams to its current revolution among the inner circles of corporate boardrooms, on Wall Street trading floors, and in government offices around the globe?

We've identified six major forces—what we call the six C's—that are pushing clean tech into the mainstream and driving the rapid growth, expansion, and economic necessity of clean tech across the globe: *costs*, *capital*, *competition*, *China*, *consumers*, and *climate*. These six forces are aligning to catalyze the growth and expansion of clean-energy solutions for transportation fuels and electricity generation; clean sources of water for drinking, irrigation, and manufacturing; and clean, environmentally

benign materials for buildings and industrial processes. Together they are creating dynamic, lucrative business and investment opportunities for established companies, entrepreneurs, and investors of all types.

**Costs.** Perhaps the most powerful force driving today's clean-tech growth is simple economics. As a general trend, clean-energy costs are falling as the costs of fossil fuel energy are going up. The future of clean tech is going to be, in many ways, about scaling up manufacturing and driving down costs.

As recently as a decade ago, most clean technologies were not ready for prime time and were often prohibitively more expensive than their conventional counterparts. Now, that's changing. Recent advances in core technology and manufacturing processes have significantly improved performance, reliability, scalability, and cost. At the same time that clean-energy technologies are getting cheaper, the costs of products and services driven by conventional fossil fuels are rising dramatically. The convergence of these two cost trends is starting to make clean tech competitive economically.

In conventional fossil-fuel power such as coal and natural gas (which together provide approximately 60% of the world's electricity), the generating technologies are mature, stable, and already widely deployed. Notwithstanding incremental technical improvements in generation and transmission efficiency, the turbines powered by burning coal and natural gas still function essentially the same way they have for decades—so their *technology* costs are relatively steady and predictable. What determines the price of conventional power is the cost of *fuel*. Since the 1970s, the costs of fossil fuels, while certainly experiencing directional gyrations, have nearly always moved in the same general direction over the long term: up.

With solar, wind, small-scale hydroelectric, geothermal, and even the nascent technology of ocean tide- and wave-generated electricity, the price-determining formula is just the opposite. There is no cost of "fuel"—the sun, the breeze, the heat of the earth, the tides and waves arrive free of charge daily. "Coal, natural gas, and oil costs move in directions that can be hard to predict," says Mark Little, former vice president of power gen-

eration at General Electric's energy unit, now director of GE Global Research. "But we can make one projection that we know will be accurate: The price of wind will always be zero. And that is a fundamental of our industry."

All of the costs involved in clean tech are in the technology used to harness and deliver the energy. And over time, as their markets expand, efficiencies improve, and production volumes ramp up to create economies of scale, the costs of new technologies consistently go down. The clearest and most well-known example of the theory of declining tech costs comes from the high-tech industry. The multimillion-dollar room-sized computers of the late 1950s have progressed, in less than a half century, to today's sub-\$1,000 laptops and iPods, which boast more computing power and data storage capacity than their gargantuan ancestors.

Moore's Law, the famous axiom of Intel cofounder Gordon Moore, states that the number of transistors on a semiconductor chip of silicon (the same base material of PV cells that deliver solar energy) will double every 18 months. In other words, the same-size chip will deliver twice the computing power at essentially the same cost—the direct cause of the falling high-tech technology cost trends we all know. A number of experts believe that clean-energy sources, such as solar, could be experiencing a kind of Moore's Law of their own, establishing a long-term trend of declining costs for clean tech.

It's not just the downward directions of clean-energy costs that contrast with that of fossil-fuel costs—it's their smoothness as well. With some notable exceptions, such as a current temporary blip in solar costs due to a global shortage of silicon for PV cells and for wind turbines due to rising steel prices and very high demand, clean-energy costs are notably less volatile than their conventional counterparts. It's a lot easier to plan your future energy budget when it's not subject to the vagaries of the world commodity markets of oil and gas described above.

One of the great advantages of most clean-energy technologies is price stability. Once you pay for a solar PV array on your rooftop or install a wind farm, there are no costs for fuels. You need to pay for your capital expenditure up front and amortize it over a 10- or 20-year loan, but beyond that, your pricing is generally stable and fixed. For a small but growing number of green-power customers—individuals and organiza-

tions that purchase a percentage or all of their electricity from clean-energy sources—the ability to lock in a consistent fuel charge for up to 10 years is a great business plum. It converts a variable budget line item into a fixed cost. Even if the initial green-power charge is a bit higher, many companies, government agencies, college campuses, and even military bases think it's worth it.

**Capital.** An unprecedented influx of capital is changing the clean-tech landscape, with billions of dollars, euros, yen, and yuan pouring in from a myriad of public and private sector sources.

Where there's money, technology expansion is sure to follow. Capital, in the form of corporate investments, VC, government grants, project finance, debt equity, and the public stock markets, is critical to the growth of any emerging sector. It provides the means to develop new technologies, build management teams, create new distribution channels, and effectively market products and services. In fact, all the major technology expansions, from biotech to the computer revolution, owe their success to an influx of capital from a range of sources. Clean tech will be no exception.

Since the 1970s, investments in clean technology have moved from primarily government research and development (R&D) projects to major multinationals, well-heeled venture capitalists, and savvy individual investors. While governments still have a significant role to play, this shift is changing the investment landscape and bringing clean technology to the commercial forefront. A number of leading companies, for example, are embracing clean-tech initiatives and investing billions of dollars in their efforts: General Electric (GE), the world's largest diversified manufacturer, plans to invest up to \$1.5 billion a year in clean-tech R&D by 2010 as part of its "Ecomagination" business strategy. BP recently launched an alternative-energy unit that will spend up to \$8 billion over 10 years to further the company's activities in solar, wind, and hydrogen. Spain-based energy giants Iberdrola and Acciona are both poised to spend billions of dollars building out their clean-energy portfolios, primarily wind power, over the coming years. In 2006, Toyota is reported to have spent an astounding \$8 billion in R&D, much of it for hybrid and fuel-cell development. Sanyo, the fourth largest solar cell manufacturer in the world



behind Sharp, Q-Cells, and Kyocera, has said it will invest \$350 million over 5 years to expand its solar operations as well.

In 2005, investment banker and Wall Street icon Goldman Sachs acquired Zilkha Renewable Energy, one of the world's leading wind-energy developers. Renamed Horizon Wind Energy, the development firm had 1,350 MW of wind-power capacity planned by the end of 2007 (1 MW of wind electricity, or 1,000 watts (W), is enough to power about 750 homes). The acquisition positioned the white-shoe Goldman Sachs firm as one of the leading players in the world of wind-farm development and finance and firmly established a new era of "big-money" wind power in the United States and abroad. The deal placed Wall Street's stamp of approval on the wind-power industry, further legitimizing the wind-energy investments of huge electric utilities such as American Electric Power, FPL Energy, TXU, and Xcel Energy. Goldman Sachs, which is branching out into other clean-energy investments, now has approximately 20 full-time investment professionals putting about \$2 billion of capital to work into such companies as First Solar, GridPoint, Iogen, and SunEdison.

Venture capitalists and investors are also taking note of the clean-tech opportunity. In fact, many of the same entrepreneurs and investors who fueled the high-tech and Internet revolutions are now leading the charge in clean tech. They are getting involved in clean tech because it is built on many of the same concepts that influenced the growth of computers and the Internet. In 2006, clean-energy investments represented more than 9% of total venture investing in the United States—up from less than 1% in 1999—and all of clean-tech investing, comprising clean energy, water, and materials, represented more than \$2.9 billion of venture investments in North America. Clean tech is now one of the largest VC investment sectors, and Cleantech Capital Group, a Michigan-based research firm, predicts it will account for \$10 billion in venture dollars in North America between 2006 and 2009, compared with \$6.4 billion in the previous 3-year period—a 56% increase.

Kleiner Perkins Caufield & Byers, best known for its investments in Amazon.com, Google, and Netscape, has created a \$200 million Greentech investment fund. Even the Carlyle Group, one of the world's largest private equity firms, is roaring into clean tech. Reviled by political activists for its close ties to two Bush administrations, global military contractors, and oil

and gas interests in the Middle East, Carlyle nonetheless sees potential for big returns in the clean-energy sectors of solar, wind, geothermal, and biomass. As clean-tech evangelist and Technology Partners general partner Ira Ehrenpreis likes to point out: “Energy-tech investing is *all* about the green, and this has nothing to do with the environment!” To the high-tech inventors, visionaries, and bankrollers jumping on board the clean tech revolution, financial returns come first.

Capital is also flowing into clean tech–focused companies through many existing and emerging retail investment products and offerings. Individuals can now invest in a handful of index-based exchange-traded funds (ETFs) and mutual funds. The first ETF representing the clean-energy sector, the PowerShares WilderHill Clean Energy Portfolio based on the ECO Index, had more than \$700 million in assets in early 2007. (WilderHill founder Robert Wilder is not related to coauthor Clint Wilder.) Other indexes have followed WilderHill’s lead: the NASDAQ Clean Edge U.S. Index (CLEN) and its liquid series (CELS), the Ardour family of “alternative” energy indexes (which include the Ardour North America [AGINA] Index), and the Cleantech Capital Group’s Cleantech Index (CTIUS). By early 2007, additional ETFs had been created based on the CELS and CTIUS indexes. Investors can also invest directly in the stocks of pure-play companies focused primarily on clean technology and large multinationals with clean-tech initiatives.

A number of mutual funds also offer investors opportunities in the clean energy and clean-tech sector. These include the New Alternatives Fund (NALFX), which is focused primarily on clean energy, and broader socially responsible investing mutual funds that have stakes in clean-tech companies, such as the Winslow Green Growth Fund (WGGFX). Another trend is the advent of “green banks,” such as ShoreBank in Chicago and New Resource Bank in San Francisco, that support green and socially responsible businesses and plan to begin offering customers high-yield, interest-bearing online banking accounts.

There’s also a major transition in capital that’s funding clean-tech growth in developing nations. In these emerging economies, most of the funding in clean energy and clean technology has traditionally come from national governments or international government-financed agencies such as the World Bank, particularly its Global Environment Facility (GEF). They are still heavily involved and will continue to be for years to come.

But today, big international banks and investment houses, among them Goldman Sachs, Morgan Stanley, Citigroup, Australia's Macquarie Bank and ANZ, Belgium's Fortis and Dexia, and RBC Royal Bank of Canada, are becoming aggressive funders of clean-energy and clean-water projects in developing countries.

**Competition.** Governments are competing aggressively in the high-stakes race to dominate in the clean-tech sector and build the jobs of the future.

From small cities to urban metropolises and from states to nations, governments at every level are competing to be leaders in the clean tech revolution. A number of factors are driving this competitive field, not the least of which is the need to build regional economies and develop high-paying regional jobs. Equally important, the competition for limited global energy and water resources is driving the clean-tech imperative to reduce the geopolitical and terrorist risks posed by dependence on resources from politically volatile regions such as the Middle East and West Africa.

Governments, via tax incentives, standards, subsidies, and other tools, can make or break the growth of any labor- and capital-intensive industrial sector. In energy, government policy has played a key role in bolstering and supporting oil, coal, natural gas, and nuclear power with extensive subsidies and tax incentives. Even in an era of record-breaking oil industry profits, Big Oil continues to receive billions in tax subsidies annually. Government policies determine issues ranging from how utilities operate to the efficiency of vehicles to the distribution of water. The clean tech revolution, in many ways, rests on the advent of long-term consistent government policies and the bolstering of subsidies for solar, wind, and other emerging sectors.

For clean tech to thrive, governments at a range of levels must embrace and support fledgling clean-tech industries with supportive policies and incentives. In cities as diverse as Bonn, Abu Dhabi, and Sacramento, forward-thinking governments are shifting regulatory and financial support away from older, polluting technologies to more efficient technologies that create jobs, reduce pollution, and make regions and countries

more economically competitive. In China, the central government is advocating three times more renewable energy by 2020 than its target for nuclear power. Japan embarked on a 10-year program in the 1990s to fund and nurture the growth of its solar PV industry, and that industry is now flourishing without any significant subsidies. Iceland is aiming to be one of the first fossil fuel-free economies—leveraging naturally occurring resources such as geothermal energy and building out a hydrogen-based economy. Germany is spending heavily to build out its solar and biodiesel industries. Sweden's prime minister, Göran Persson, has announced the ambitious intention for his country to be oil free by 2020. At least eleven other developing nations ranging from Cambodia to Turkey have some sort of national policies in place to promote, incentivize, or directly fund clean-energy development.

Across the globe, many regional and national governments are pushing initiatives that could result (and in some cases already are resulting) in more than 20% of their energy coming from renewable sources. A shift of unprecedented proportions is afoot—although clearly, much more will need to be done to put clean technologies squarely in a leadership position.

In the United States, the Republican and Democratic governors of New York, Pennsylvania, California, Montana, New Mexico, and other states are calling for massive investments in clean energy and clean technology. California recently increased its renewable portfolio standard by accelerating its 20% renewable energy target to 2010 (7 years earlier than initially targeted) and calling for 33% of California's electricity to come from clean-energy sources by 2020. Its landmark greenhouse-gas reduction legislation, signed by Governor Arnold Schwarzenegger in September 2006, is the first-ever such bill in the United States requiring major industrial emitters to cut GHG emissions 25% by 2020. Although traditional industries such as oil, cement, and some manufacturers said the bill would hurt business, venture capitalists, investors, and entrepreneurs lobbied hard to pass it. The state's Climate Action Team, formed by Schwarzenegger in 2005, predicts that the legislation will create up to 83,000 new jobs worth \$4 billion in personal income by 2020.

Unfortunately, even as local governments are acting, the administration of President George W. Bush has fallen far behind other nations in pursuing aggressive clean-tech initiatives and providing long-term guidance and

incentives. While Japan and Germany have been championing clean tech for some time, the U.S. federal government has basically been missing in action. Once the U.S. federal government finally gets on board, in an aggressive way, it will augment significant developments already in place at the state level and around the globe.

**China.** Clean tech is being driven by the inexorable demands being placed on the earth not only by mature economies but also by the explosive demand for resources in China, India, and other developing nations. Their expanding energy needs are driving major growth in clean-energy, transportation, building, and water-delivery technologies.

China is emblematic of the resource constraint issues facing our planet—it is currently the earth’s number-one consumer of coal, burning more of it each year than the United States, India, and Russia combined. It is now the second largest consumer of oil on the planet behind the United States, recently eclipsing Japan, and also the world’s largest consumer of steel, meat, and grain. With a projected migration of more than 400 million people from rural areas to cities by 2020 (equal in size to three New York Cities per year), China will not be able to sustain its growth if it doesn’t widely embrace clean technology.

The Chinese government is starting to understand this and in 2006 committed to investing up to \$180 billion over 15 years to meet nationally mandated targets for clean energy. China is planning to have 60 GW of renewable energy (not including large hydroelectric) by 2010 and 120 GW by 2020. If the country meets these national mandates, clean-energy sources will represent upward of 10% of total generating capacity by 2020.

And it isn’t just China that is embracing clean tech. Across the globe, developing nations in Asia, Africa, and South America view clean-energy sources such as wind, solar, and biofuels not as niche novelties or environmentalist-motivated “alternatives” but as a critical, urgent, and growing piece of a diversified energy mix needed to fuel their rapidly developing economies and middle classes. With the hypercharged economies of China and India both growing 5% to 9% annually, there’s a palpable feeling of wanting to deploy and use any energy source they can

get their hands on. There's less of a perceived conflict between established energy sources and newer, cleaner options. Wind, solar, small hydroelectric, biogas, biofuels—we need all of those, these nations seem to say. As much as possible, as soon as possible, and above all, as cheaply as possible.

This adds up to unprecedented opportunity for clean-tech manufacturers and investors in meeting the power and water needs of billions of people. The profit opportunity to serve the emerging markets in China and countless other nations is expanding for both large corporations and emerging start-ups. That's why today the world's leading wind, solar, and other clean-tech providers are already moving into the Chinese market via joint ventures with local companies and other avenues.

Tapping these markets won't be easy, but the growing, energy-hungry middle classes of developing nations require massive new water and energy infrastructure projects, be they wind farms off the Indian coast, ethanol plants in China, or desalination facilities in Algeria. And rural communities, which still represent nearly 50% of the global population, are in desperate need of finding creative ways to meet the resource needs of their residents. In India, some 56% of the population's 700 million rural residents lack reliable access to electric power. The nation wants to deliver electricity to all of them by 2012—50% of it from renewable sources including wind, solar, and biogas.

China, emblematic of this mounting and critical need for clean and efficient energy, transportation, water, and materials, offers up a unique opportunity for investors and innovators. The nation will be one of the largest consumers of clean technologies and a potentially inexpensive manufacturing base for export to other nations.

**Consumers.** Savvy consumers are demanding cleaner products and services that use resources efficiently, reduce costs, and embrace quality over quantity.

Without consumer demand, no market would materialize. Today, high energy prices, polluted ecosystems, and growing awareness of climate change and the geopolitical costs associated with fossil fuels are driving a shift in consumer attitudes and consumer demand for clean-tech products

and services. That's forcing companies that sell to consumers—from appliance makers to auto manufacturers—to produce cleaner, more efficient products and market them aggressively.

Companies such as organic food purveyor Whole Foods Market, the fastest-growing grocery chain in the United States, have proven that huge shifts in mainstream consumer perception, behavior, and spending are possible. The demographic sector known as LOHAS—lifestyles of health and sustainability—has swelled to 50 million people, or one sixth of the U.S. population, according to the Natural Marketing Institute. Even more significantly, those consumers spend more than \$220 billion annually on a wide range of products and services, including yoga, organic foods and cosmetics, acupuncture, ecotourism, and organic cotton clothing, according to the *LOHAS Journal*. Even if that figure is inflated, when mainstream retailers like Safeway and Wal-Mart Stores start embracing organic foods as they have, it's clear that there's a shift going on that makes consumer markets ripe for clean tech if it's marketed effectively.

In fact, there is already some indication of a significant and expanding consumer interest in clean-tech products and services. Not unlike the explosive growth of the organic foods market, clean technologies such as solar, wind, and biofuels are seeing annual growth rates exceeding 30%. The number of EnergyStar homes, so designated by standards of the U.S. Environmental Protection Agency because they are equipped with the most efficient heating and air-conditioning systems and appliances, have gone from zero in 1995 to more than 130,000 in 2004, comprising up to 40% market share of new homes in some regions. Who is driving this demand and growth? Both early adopters, who installed the first solar PV system in their neighborhood or purchased an early model Toyota Prius, and mainstream customers, who are installing high-efficiency water heaters, buying higher-mileage cars, insulating their homes with recycled denim, and demanding efficient EnergyStar appliances and windows.

In clean tech, broad, growing mass consumer markets are already coming into being for hybrid cars in the United States (where hybrid sales nearly tripled between 2004 and 2006), solar hot-water heaters and electric scooters in China, and energy-efficient appliances and lighting in Europe, Asia, and the United States. Whether it's efficient compact-fluorescent or light-emitting diode (LED) lightbulbs at Sears and

Home Depot or ethanol from Wal-Mart's 400 filling stations at its Sam's Club stores, clean-tech products are squarely in the consumer mainstream.

Another factor impacting the consumer trend is the newly minted consumer classes of the developing world. Fueled by their nations' boom economies, these consumers won't just be buying clothes and gadgets—they'll be using energy at a modern, consumer-driven pace that their parents and grandparents scarcely could have imagined. Economists estimate that the Chinese middle class, already more than 100 million people strong, will reach 200 million by 2010. The same trend is occurring in India and, to a lesser extent, in other developing nations. That's both a driver and an opportunity for clean tech, with hybrid cars, energy-efficient appliances, and renewable energy-powered homes and apartments already gaining significant traction in rapidly developing nations.

**Climate.** The debate around climate change has gone from question mark to peer-reviewed certainty, and smart businesses are taking heed.

Alarm is growing about the climate-change consequences caused by our continued dependence on carbon-intensive, GHG-emitting energy and transportation sources and manufacturing processes. Scientific data and research overwhelmingly support this growing concern. Eleven of the hottest years on record occurred between 1995 and 2006; the United States and Japan both recorded the highest number of extreme weather events in the form of hurricanes and typhoons in 2005. The devastation of Hurricane Katrina in particular brought the issue of the effect of warming oceans on storm severity to the forefront of public attention.

NASA released a report in 2006 showing that the Greenland ice belt is melting far faster than earlier believed and could cause considerable global sea-level flooding. The National Academy of Sciences delivered a 155-page report to the U.S. Congress in 2006 supporting the human-climate change connection. A panel of climate scientists reported that the "recent warmth is unprecedented for at least the last 400 years and potentially the last several millennia" and that "human activities are responsible for much of the recent warming." And with insurance giants such as Swiss Re and Munich



Re thinking twice about climate impact on the issuance of their policies (try getting an insurance policy for an oil rig in the Gulf of Mexico), the climate issue is coming front and center for companies, governments, and individuals. Human impact on climate is clear and concise—we are adding more carbon dioxide (CO<sub>2</sub>) into the atmosphere now than at any other time in recorded history.

That's driving clean-tech investment and deployment and becoming an increasingly important factor in assessing investment risk factors. Global companies from DuPont to Wal-Mart are investing heavily to promote energy efficiency and clean tech in their operations to reduce their GHG contributions. Government and private carbon trading schemes, in which companies earn financial credits for cutting CO<sub>2</sub> emissions and pay penalties if they don't, are creating further economic incentives for companies to operate more efficiently and run clean. Forward-looking U.S. companies and investment managers, even without their government's participation in the Kyoto Protocol to the United Nations Framework Convention on Climate Change, are joining their European and Japanese competitors to reduce their production of CO<sub>2</sub>. They believe, as we do, that future carbon regulation is inevitable and are following a fundamental principle of business innovation: Be proactive, not reactive.

For businesses and investors, the climate-change issue works as a two-pronged driver. The increased regulation of CO<sub>2</sub> and other GHGs will pump up worldwide demand for technologies that deliver energy or power transportation with reduced or zero amounts of GHGs, growing the markets for those technologies. At the same time, investors will increasingly assess companies in all industries on their downside risk from carbon emissions and their upside potential from reducing them. A growing number of leading investment banks, such as Innovest Strategic Value Advisors and Sanford C. Bernstein, have begun rating stocks in terms of carbon risk and establishing funds of potential winners.

“As an investor, do you believe that we're going to take climate change seriously in terms of legislation?” asks Mark Trexler, president of Trexler Climate + Energy Services, a firm in Portland, Oregon, that advises companies and utilities on carbon-reduction strategies. “If you do, then figure it in to your investment decisions. If you're right, you'll be way ahead in the long run. To completely ignore it, in terms of investment decisions, would be a terrible thing.”

These powerful global forces—the six Cs—have put clean tech onto center stage and awakened a diverse range of stakeholders across the world. The clean tech revolution is not about environmental do-goodism and is not a rejection of business and technology. Instead, it embraces capital, business, and technological innovation and provides a viable new path for a world that's reaching resource limits and dealing with unprecedented challenges. Governments, investors, companies, and entrepreneurs that seize the opportunity of clean technology are positioned to reap significant benefits and profits.

From Beijing to Berlin, from San Francisco to Bangalore, the clean tech revolution is well under way. It will determine which regions lead and prosper and which regions are left drowning in their own effluents, choking on their own emissions, and struggling to compete in a world that is leaner, greener, and less reliant on fossil fuels.

## WHO STANDS TO WIN?

Is it too late to participate in the clean tech revolution? Have all the big players cornered the market? Has all of the smart capital been invested? Have all of the best innovations been developed? Certainly not. Although the rapid pace of change in clean-tech developments and breakthroughs rivals that of other tech sectors, the infrastructure challenges of energy, materials, and water mean that the clean tech revolution will be a lengthy one compared with the almost instant revolution of personal computers, the Internet, and Wi-Fi. We won't simply wake up one day and find that an entire city has switched from coal to wind power. So it's far from being too late to get started. The clean tech revolution is, despite decades of development to date, still in the early to middle stages of transforming the world's largest markets.

Take the energy industry. It took coal nearly 100 years to bypass traditional energy sources (such as the burning of wood) as the world's primary energy source. It then took oil nearly 100 years to surpass coal usage. Natural gas has been more than 100 years in development and now represents about 20% of global primary energy use. Similarly, it will take new renewables, such as wind, solar, and biofuels, 10, 20, or 30 years or more to catch

up with coal, oil, and natural gas. That's the reality of clean tech and one of the reasons why long-term thinking is so crucial.

But herein lies the opportunity. The clean tech revolution is actually already 30 to 50 years in the making; the first conversion of sunlight to electricity in a solar PV cell, for example, took place at Bell Labs in 1954. Moving forward, clean technology will exhibit both disruptive sudden advances and more deliberate, incremental change. In a world of increasingly constrained natural resources, it's hard to conjure up a sector that offers more promising long-term returns and rewards.

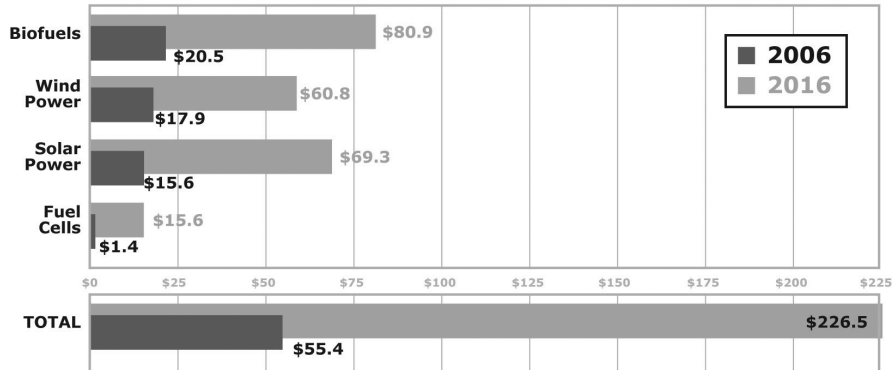
Unlike the Internet, which went through a rapid boom-and-bust cycle—a classic bubble—the transition to new energy, transportation, advanced materials, and water technologies will look more like a long boom. To be sure, there will be periods of high growth spurts and then retrenchment. There will be occasional irrational exuberance. But with the right combination of policy, capital, and technology, the exploding global market for clean tech will not abate anytime soon.

Consider some of these facts: According to Clean Edge research, the global biofuels market (manufacturing costs and wholesale pricing of ethanol and biodiesel) will grow from \$20.5 billion in 2006 to \$80.9 billion by 2016. Wind power (new-installation capital costs) will expand from \$17.9 billion in 2006 to \$60.8 billion in 2016. The solar PV industry (including modules, system components, and installation) will grow from \$15.6 billion in 2006 to \$69.3 billion by 2016. And the fuel-cell and distributed-hydrogen market will grow from \$1.4 billion (primarily for research contracts and demonstration and test units) to \$15.6 billion by 2016.

In total, the four clean-energy sectors tracked by Clean Edge amounted to \$55.4 billion in 2006, larger than the international music industry. We project that the wind, solar, hydrogen, and biofuels markets will grow fourfold to more than \$226 billion by 2016.

With cities, states, and nations around the globe planning to generate at least 20% to 30% of their total energy from renewables such as wind, solar, and biofuels by 2030, investments in clean energy are likely to continue to rise—rewarding investors and companies that get on board now.

### Clean Energy Projected Growth 2006-2016 (\$US Billions)



Source: Clean Edge, 2007

## HOW TO PROFIT: THE EIGHT MAJOR CLEAN TECHNOLOGIES

In *The Clean Tech Revolution* we show how clean technologies offer entrepreneurs, individual investors, recent college and business school graduates, corporate executives, policy makers, and others the opportunity to profit financially while providing solutions to some of the greatest issues facing humankind. Our book will help you spot the winners among technologies, companies, and regions likely to reap the greatest benefits from clean tech—and show you why the time to act is now.

In the following chapters we highlight the eight major clean technologies that we believe offer investors the best opportunity. In narrowing down the list, we needed to exclude some emerging clean technologies, but we believe the following list offers the greatest near- to midterm opportunity. These are the top eight technologies and sectors that we'll cover in detail:

- **Solar energy.** The solar-power market offers perhaps one of the greatest opportunities among its clean-tech peers. Not only is the worldwide solar market growing by 30% to 50% per year, but the same technologies that enabled the semiconductor and computer revolution are now being

leveraged in the solar market. Savvy venture capitalists, companies, and industry experts believe that solar power will be cost-competitive with conventional retail electricity rates before 2020. The solar industry, we believe, will be dominated by those that can significantly lower costs for solar PV modules, drive down installation costs, and integrate solar PV into everything from building rooftops to utility infrastructure.

- **Wind power.** Wind energy has been expanding rapidly since the mid-1990s—right up there with solar. From 1995 to 2006, global cumulative installed wind-power capacity expanded fifteenfold, from less than 5,000 MW to more than 74,000 MW. While investing in some of the current wind giants such as GE, Denmark’s Vestas Wind Systems, and Spain’s Gamesa could offer lucrative opportunities, there are other emerging avenues for entrepreneurs. The advent of smaller-scale community wind projects could enable local farmers, developers, and financiers to reap profits. And the market for new materials for turbines and control systems for wind farms is still relatively untapped. As nations such as Germany and Denmark get upward of 15% of their electricity from wind, and other nations and regions push to reach similar targets, the wind industry is the current champion of new renewables.
- **Biofuels and biomaterials.** Today, Brazil gets more than 30% of its automobile fuels from sugar cane–based ethanol. In the United States, ethanol is nearly a 5-billion-gallon-a-year industry, on target to reach 7.5 billion gallons (about 5% of total gasoline consumption) around 2010. One of the greatest opportunities will lie in distilling fuels and creating materials from cellulosic nonfood crops such as switchgrass and jatropha. Entrepreneurs and companies that can crack the cellulosic ethanol code, along with those that develop new methods of refining and distributing biofuels, are poised to profit from the mass adoption of biofuels and biomaterials.
- **Green buildings.** Today’s green buildings use some 30% less energy than their comparably sized nongreen counterparts (some save much more), and they’re generally brighter, healthier, and more aesthetically pleasing. Often built with little or no additional up-front cost, green offices, for instance, pay back not only in energy savings but also in greater employee retention, attendance, and productivity. Green build-

ings of all stripes, including houses, apartment buildings, schools, and condominiums, are using advanced lighting, new building materials, efficient appliances, and energy-management systems to reinvent the buildings we call home.

- **Personal transportation.** Clean transportation is changing the means of mobility for consumers and workers across the globe. It includes today's HEVs as well as plug-in hybrids and the revival of electric-vehicle technology in high-powered, innovative, and even sexy designs. Imagine a car that can get the equivalent of 100 miles per gallon (mpg) from a gallon of conventional gasoline. The technologies to make this a reality already exist—and offer individuals, forward-thinking companies, and entrepreneurs unprecedented opportunity. And we're not talking just about cars but also about more efficient and less polluting motorcycles, scooters, and mopeds.
- **Smart grid.** In the future our electric grid, which is woefully outdated, will start to look a lot more like the Internet. Homes and businesses will no longer be just energy consumers but also energy producers. This two-way flow of electrons will transform the electric utility industry. Already, some companies such as Itron are deploying smart meters that enable utilities to better track and monitor consumption and performance, and companies such as CURRENT Communications are working to communicate, monitor, and manage the flow of electrons. New interconnect standards—regulations that guide how utilities access, quantify, and pay for distributed-energy sources—are also changing the utility landscape. The smart grid, while still a relatively new concept, offers one of the brightest opportunities in the clean-tech marketplace as it works to transform decades-old utility infrastructure.
- **Mobile applications.** The need for portable, lightweight, long-lasting sources of power spans four huge areas: consumer devices for today's untethered masses; the military; remote, rural villages in developing nations; and disaster recovery zones, from the U.S. Gulf Coast to the Indian Ocean. Often overlooked by casual observers of clean tech, these areas represent huge opportunities for the deployment and growth of high-efficiency solar panels, portable fuel cells, nanotechnology-based advancements in batteries, and many other clean technologies. In many

areas the U.S. military is at the leading edge of investing in and deploying a range of these technologies. The Pentagon's vast funding arsenal clearly spells big business opportunities in mobile clean tech.

- **Water filtration.** Although the earth has plenty of water, clean and potable water is becoming increasingly scarce. And while energy security is currently capturing the media's attention and attracting significant pools of capital, water will not be far behind. In places such as Israel and Singapore, new forms of desalination technology are converting saltwater to tap water. Nanotechnologies are being used to filter and purify water once deemed unusable. Although water technologies are the traditional domain of big business such as GE and Siemens, a number of smaller players are also competing in the effort to provide the world with clean water. With an estimated 1 billion people on the planet without access to clean water and the increasing threat of "water shocks"—abrupt water shortages due to pollution, rapid water-table depletion, or natural disasters—the ability to deploy clean technologies to enable water filtration and purification is likely to expand considerably in the coming decades.

After our review of the top eight clean technologies, we follow with a chapter titled "Create Your Own Silicon Valley" that examines the paths that city and regional governments around the globe can take toward the payoffs from clean-tech leadership: business development, job growth, and improved quality of life. We wrap up the book with a chapter that highlights successful clean-tech marketing examples and looks at both the hurdles and opportunities in moving clean tech into a mass market embraced by millions of mainstream consumers worldwide.

In each technology chapter, we also provide a list of 10 companies or organizations that are likely to be at the forefront of clean-tech activities, as well as *Clean-Tech Consumer* sidebars that present brief snapshots of particular products and services most likely to show up in your home, office, or car now or in coming years. Throughout the book, we also highlight breakthrough technology and business-model opportunities for entrepreneurs and "intrapreneurs" (those leading entrepreneurial initiatives within large companies).

## WHAT'S NOT CLEAN TECH: NUCLEAR AND COAL

At first blush, the notion that a technology producing radioactive waste could ever be considered “clean” sounds ludicrous. But global warming’s threat to the planet has cast this debate in a new light. Nuclear generation’s lack of GHG emissions has brought new supporters on board. We, however, are not among them. There is a long list of reasons why we do not consider nuclear power clean with current technology: radioactive waste disposal and storage challenges; proliferation of nuclear material in a world that lived through the terrorist attacks in the United States on September 11, 2001; and the security threat of nuclear power stations as inviting terrorist targets. In addition, nuclear plants use vast amounts of carbon-intensive energy and materials such as cement in their construction. They also require large amounts of water in their cooling operations, which can further constrain development and operation. France, long considered a model for the success of nuclear power, experienced brown-outs in the drought-prone summer of 2005 because French nuclear plants couldn’t get enough water to run at peak capacity.

But our number one argument against nuclear power is found right on the bottom line: Multibillion-dollar nuclear plants are simply not cost-effective compared with other energy sources. No utility in the United States has completed a nuclear plant ordered since 1973, and money has been one of the biggest reasons why. Nuclear advocates talk about the low price per kilowatt-hour of nuclear energy once a plant’s up and running, but that doesn’t include life-cycle costs such as decommissioning and accident liability insurance. A new nuclear plant costs around \$1.5 billion, according to industry estimates. Most outside estimates place the tab at closer to \$2 billion to \$5 billion (not including government subsidies and incentives). Insurance costs are so prohibitive that the U.S. government has to foot the bill for any accident costs above \$10.9 billion. The nuclear industry simply wouldn’t exist without extensive government subsidies.

There’s also the issue of scale. The U.S. Department of Energy’s Energy Information Administration projects that the world will need 14 terawatts (14,000 GW) of new energy sources between now and 2050 to keep up with growing demand. It would require 14,000 one-GW nuclear power plants to cover the projected gap in global new energy demands. There are currently fewer than 450 nuclear plants operating in the world today,



roughly 100 of them in the United States. This estimate is admittedly a hypothetical, all-or-nothing game scenario, but even a fraction of that number means a hugely expensive proposition with a publicly unacceptable level of nuclear proliferation.

So until safeguards are in place, nuclear containment is achievable, realistic waste solutions are deployed, and costs are accurately calculated and accounted for, we strongly disagree with current political efforts in the United States and elsewhere to “revive” the nuclear power industry. That verb is not lost on Amory Lovins, longtime energy-efficiency and clean-energy guru whose consulting clients include Wal-Mart and the Pentagon. “Paying new subsidies to the nuclear power industry is like defibrillating a corpse,” says Lovins, cofounder and CEO of the Rocky Mountain Institute in Snowmass, Colorado.

The other conventional energy source that aspires to be clean, but doesn’t make the cut, is “clean coal.” A number of proponents and innovators are working to develop new forms of burning coal with reduced pollutants and GHG emissions. However, at present, we believe that *clean coal* is an oxymoron for a myriad of reasons, including the sheer number of coal mine–related deaths and the fact that coal-fired plants, even some cleaner ones, are major contributors to serious illnesses such as asthma, heart disease, and mercury poisoning. A more accurate label would be *cleaner* coal, but we remain skeptical on whether its technologies can really put a significant dent in carbon emissions. Sure, clean coal is better than dirty coal, but it’s a long way from sharing the clean-tech label with wind, solar, small-scale hydroelectric, and other emissions-free energy sources.

That said, there is one clean-coal technology that seems to offer some future hope, with an increasing chorus of diverse interest groups calling for it: integrated gasification controlled cycle, much better known by its initials IGCC, or simply coal gasification. This process essentially breaks coal down into gaseous components, including natural gas, a cleaner-burning fossil fuel, and CO<sub>2</sub>. That enables the easier use of carbon sequestration, a promising but still widely developmental technique of capturing CO<sub>2</sub> and storing it underground or underwater—that is, out of the earth’s atmosphere. The technique remains expensive and unproven on a large scale, and we believe it is years away from deployment.

The best way to “clean up” coal is to replace as much coal-fired power as possible with electricity from wind, solar, biomass, geothermal, tidal, and

other renewable clean-tech sources and to make both clean and nonclean power generation as efficient as possible.

## WHAT WE MEAN BY INVESTING

In *The Clean Tech Revolution* we talk about investing in the broadest terms—and highlight opportunities for everyone from individual investors to corporate managers to politicians to recent college graduates. When we refer to investing opportunities, we are referring not only to the investment of money or capital but also to the investment of time, vision, energy, and talent. Our focus includes:

- **Individuals.** We highlight potential sectors for investing in clean-tech stocks and mutual funds as well as opportunities in emerging clean-tech markets for career growth for current workers and new graduates. We also look at how consumers can purchase clean-tech products and services that can improve their lives and save them money.
- **Venture capitalists and entrepreneurs.** We track investor commitments to innovative, early-stage companies and look at some of the emerging companies that are on track to transform the energy, transportation, water, and materials markets.
- **Corporations.** We delve into the investments in clean-tech research, development, and deployment being made by some of the world's largest multinationals and explain how their commitments to clean technology are reconfiguring the business landscape.
- **Governments.** We show how governments at the regional, state, and national level can focus their time and money to become clean-tech revolutionaries—in the process creating jobs, building robust economies, and positioning themselves for the future.

What we do not do in this book, however, is make investment recommendations in specific stocks and securities. Instead, our mission is to shine a light on areas of emerging opportunity; highlight key technologies, companies, and players; and map out areas of potential entrepreneurial breakthroughs. We believe this approach serves our readers best—by look-

ing out over the next 2, 5, and 10 years at trends that have the power to dramatically shift the business, economic, and political landscape.

## CLEAN TECH NOW

*The Clean Tech Revolution* explains how major trends in clean tech will continue to unfold and grow, offering readers vast new opportunities for investment, employment, and lifestyle choices. We will explain why clean tech, over and above the arguments for environmental protection and climate-change mitigation, is an economic imperative. Nations, companies, and investors who dismiss or disregard these trends run a strong risk of falling behind their competitors in attracting top talent and generating profits in the global marketplace.

So let's get started on a closer look at the clean tech revolution and how you, your business, and your government can participate. A world facing unstable energy prices, resource shortages, and environmental challenges can't afford to wait, and the most innovative and visionary companies, investors, and governments are already on board. It's time for you to join them.

