Introduction

THE BIRTH OF CLEAN TECH

Just west of Northern California's windswept Altamont Pass, where some of America's first clean-energy entrepreneurs installed wind turbines three decades ago, the seeds of a new energy revolution are taking root. Here in the Bay Area suburb of Livermore, at the sleek Silicon Valley–style headquarters of Bridgelux, engineers in sterile "bunny suits" are fabricating wafers that house the tiny components for light-emitting diode (LED) lighting technology, the world's most energy-efficient form of illumination. Bridgelux's proprietary process, known as metal-organic chemical vapor deposition (MOCVD), is accomplished by intricate state-of-the-art machines costing as much as $2.5 million each—and by the well-trained, highly skilled workers who run them.

LEDs, the next wave in mass-market energy-efficient lighting, use up to 90 percent less electricity and last 25 times longer than comparable incandescent bulbs. The Bridgelux facility in Livermore opened in 2009 and was the first new LED complete-fabrication facility

opened in the United States in more than two decades. "There are 71 new LED factories in China, and none of them have the technology to do this yet," says Steve Lester, the company's chief technology officer and vice president of R&D, referring to the MOCVD process. "I don't want to move to China. I've been in the LED business for 24 years, and I'm really passionate about this. If we can find a way to keep making LEDs in the U.S., we will."

Bridgelux, a venture-capital-backed startup headed by top Silicon Valley executive Bill Watkins, is well-funded ($220 million raised by March 2012) and growing. In an industry sector that has 95 percent of its products made in Asia and Europe, Bridgelux employs 250 people in Livermore, and 140 of them are in highly skilled engineering and R&D jobs. The company has big plans for expansion and good prospects for market acceptance. But even if the company succeeds, will Bridgelux be part of a much broader trend that revitalizes the U.S. economy in the face of unprecedented world competition? Or will it just be a unique, feel-good story in a gloomier context of diminished American leadership in global business, innovation, and economic growth?

The answer to that question will depend heavily on critical decisions that the nation's policymakers, business leaders, and investors make in the next three to five years. We strongly believe that the U.S. has the brainpower, the business acumen, and the educational, financial, and natural resources to be the leading nation, with the most innovative and successful companies, in this new and emerging revolution. But we believe just as strongly that this will not occur if we continue on our present course. That is why we wrote this book.

CLEAN TECH AT THE FOREFRONT

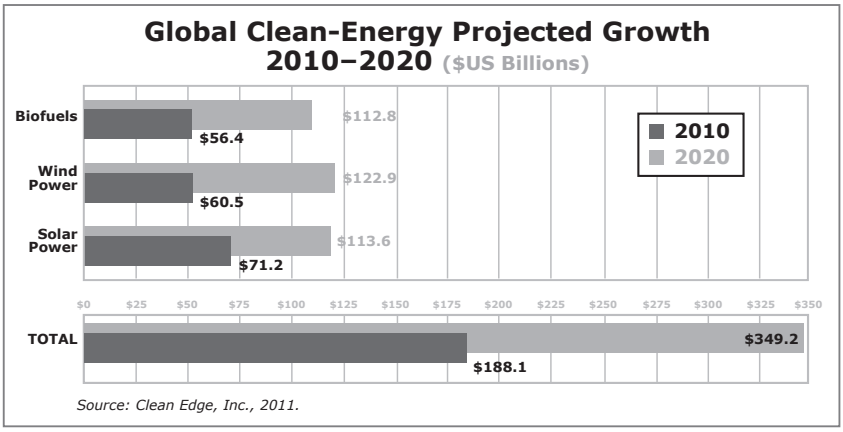
As we forge ahead in the second decade of the 21st century, the U.S. economy is at a crossroads. It faces a frustratingly slow economic recovery from a devastating recession, record debt lev-

els, high unemployment, a declining manufacturing base, rising income inequality, and a host of other challenges. At the same time, a dynamic, fast-growing, and potentially disruptive new industry, clean tech, has moved to the forefront as a central component of economic competitiveness among companies, cities, states, regions, and nations.

This did not happen overnight. Solar photovoltaic (PV) module technology, for example, is more than 50 years old—it was invented at AT&T's legendary Bell Labs in 1954, with an eye toward powering spacecraft with the sun. The first large-scale wind turbine in the U.S. debuted in 1941. But for several decades, solar power, wind energy, and other current clean-tech mainstays languished far from the mainstream, the province of research scientists and off-the-grid, back-to-the-land devotees of "alternative" lifestyles.

Over the past ten years, however, clean tech—any product, service, or process that harnesses renewable materials and energy sources, reduces the use of nonrenewable natural resources, and cuts or eliminates emissions and wastes—has unquestionably claimed its place as a large-scale global industry. Clean tech encompasses a wide range of technologies in the energy, transportation, materials, and water sectors, including solar and wind power, hybrid vehicles, green buildings, high-efficiency lighting, and water-filtration membranes. It is now embraced by many of the world's largest corporations and most influential investors, and by virtually all national governments in the industrialized world. Like the innovation-fueled technology revolutions that came before it in the late 20th century—computing, high-speed telecommunications, and the Internet—all led, it should be noted, by the U.S.—clean tech has enjoyed a very rapid growth trajectory as a global industry. From 2000 to 2010, the combined global market for solar PV and wind power grew more than twentyfold, from $6.5 billion to $131.6 billion. Add to that the $56.4 billion global biofuels industry and the "Big Three" clean-tech sectors

accounted for $188.1 billion in 2010—larger than the market for all retail online sales in the U.S.—and are projected to grow to nearly $350 billion by 2020.



Clean-tech-related products and services have become a major component of business strategy, investment, and revenue for many of the world's largest industrial giants, among them General Electric, Siemens, ABB, and Samsung. The biggest names in high tech, notably IBM, Google, Intel, and Microsoft, have embraced smart-grid technologies and other aspects of clean tech as a major new business opportunity.

In the arena of entrepreneurs and venture capital, clean tech has grown in the past decade from a tiny sliver of VC investments in the U.S. to nearly a quarter of total VC dollars in 2010, according to annual tracking by the Cleantech Group research firm. That puts clean tech right up there among traditional VC-attracting sectors such as software, telecommunications, biotech, medical devices, and Internet technology.

Clean-Tech Venture Capital Investments in U.S.-Based Companies as Percent of Total 2001–2010

Year	Total Venture Investments ($Millions)	Clean-Tech Venture Investments ($Millions)	Clean-Tech Percentage of Venture Total
2001	$37,624	$458	1.2%
2002	$20,737	$651	3.1%
2003	$18,789	$807	4.3%
2004	$21,699	$760	3.5%
2005	$22,535	$1,158	5.1%
2006	$26,010	$2,685	10.3%
2007	$29,901	$3,761	12.6%
2008	$28,105	$6,120	21.8%
2009	$18,276	$3,553	19.4%
2010	$21,823	$5,055	23.2%

Source: Cleantech Group, 2011, with Clean Edge analysis. Clean-tech venture investment includes seed funding and follow-on rounds prior to private equity activity related to stake acquisitions or buyouts. Investment categories include agriculture, air & environment, energy efficiency, energy generation, energy infrastructure, energy storage, materials, manufacturing/industrial, recycling & waste, transportation, and water & wastewater.

DEEPLY IN THE MAINSTREAM

In terms of deployment, clean tech has become a key, growing, and increasingly mainstream component of energy supply and daily life in many places around the world. Consider the following:

- The states of Iowa, North Dakota, and California each generate more than 10 percent of their electricity supply from wind, solar, and/or geothermal power.

- U.S. renewable energy reached a major milestone in the first quarter of 2011, surpassing energy production from nuclear power. Renewable energy sources (biomass/biofuels, geothermal, solar, hydroelectric, wind) provided 2.245 quadrillion BTUs of energy, or 11.73 percent of total U.S. energy production, in the first quarter of 2011, beating out nuclear power's 2.125 quadrillion BTUs. While nuclear power's contribution has remained relatively unchanged in recent years,

the contribution of renewable energy has shown steady double-digit annual growth.

- In Denmark, Portugal, and Spain, wind power contributes more than 15 percent of the electricity supply nationwide. During March of 2011, wind became Spain's leading source of electricity for the first time—covering 21 percent of the country's demand for the month and beating out other sources like nuclear (19 percent) and hydroelectric (17 percent).

- Just a few years ago, residential solar power installation in the U.S. was a highly fragmented, mom-and-pop service. Now, Americans in many states can get solar price quotes and sign up for installation on a Saturday afternoon visit to Home Depot or Lowe's; both home improvement giants are partners with nationwide solar installer/lessor companies like SolarCity, Sungevity, and SunRun. Speaking of mainstream, there are even solar panels on the Infineon Raceway NASCAR track, in Sonoma, California, supplying 41 percent of the speedway's electricity needs.

- In 2000, fewer than 10,000 hybrid electric vehicles were being driven on U.S. roads, and only two models, the Honda Insight and the original Toyota Prius, were available worldwide. In 2010, more than 1.4 million U.S. motorists drove hybrids, and 30 models, from carmakers in Asia, the U.S., and Europe, were on the world auto market. Ford, the number-two automaker in the U.S., has predicted that by 2020, one of every four cars it sells will have electric power, either as a hybrid or as a 100 percent electric vehicle (EV).

- Only three commercial buildings in the world in 2000 were certified as green with the LEED (Leadership in Energy and Environmental Design) designation from the U.S. Green Building Council. By the end of 2010, more than 8,100 commercial structures had been LEED certified globally.

- In the five years from 2006 through 2010, Walmart and Sam's Club stores sold more than 460 million energy-saving compact fluorescent (CFL) lightbulbs. CFLs and LEDs together accounted for more than 20 percent of lightbulb sales worldwide in 2010.

THE COMPETITIVE IMPERATIVE

Every day, new examples highlight the growing mainstreaming of clean tech. But clean tech's business growth and increasing ubiquity are only part of the story. As we will outline in this book, clean tech has become the most critical industry of the 21st century—an essential component to global economic success for all developed countries, and increasingly for developing nations as well.

To some, that may seem like a bold statement. And let's be honest: In terms of current annual revenue, even the giants of clean tech pale in comparison with oil behemoths like ExxonMobil, Shell, BP, Chevron, and ConocoPhillips. But consider that in the first half of this century, the move to cleaner, more efficient, less carbon-intensive energy will hugely impact, if not completely transform, many of the largest industries on earth, including electric power utilities, suppliers of transportation fuel, residential and commercial construction companies, and automotive and aerospace manufacturers. This transformation is well under way from Shanghai to Stuttgart, from San Francisco to Seoul.

"The low-carbon economy will absolutely survive the recession," John Fernandez, the U.S. assistant secretary of commerce for economic development, told a nationwide convention of economic development officials in June 2011. "China, Germany, Brazil, and other countries are making new bets on technology that will be critical to manufacturing and moving all industries forward. There is only one path forward for the U.S.—to invest in clean technologies and energy efficiency to drive global economies."

Fernandez has plenty of company. An increasingly loud chorus of influential voices—among them German chancellor Angela Merkel, GE chairman and CEO Jeffrey Immelt, and renowned Harvard Business School professor Michael Porter—have begun pointing to clean tech as the key driver of technology innovation, high-skills job creation, and global economic competitiveness in the years and decades ahead.

PROGRESS REPORT: THE SIX C'S

In our 2007 book *The Clean Tech Revolution*, we identified six global forces driving the rapid growth of clean energy, transportation, and related technologies around the world: Costs, Capital, Competition, China, Consumers, and Climate. All are still critical factors, but five years later, in the context of a dynamic and rapidly changing industry, we've made some modifications. With China having emerged as the key competitor to watch in the global clean-tech industry, we've combined China and Competition into one "C" and added a new one—Connectivity—reflecting the strong influence of today's high-speed, ubiquitous communications technology and culture on the growth of clean tech.

Here's a small snapshot of what's happened in the realm of each of the Six C's since the publication of *The Clean Tech Revolution*:

Costs. The basic premise here—that the costs of clean technologies

will fall over time, as they do in the high-tech industry—has absolutely been borne out in recent years. Solar PV prices have been the most striking example. The cost of solar power worldwide (including both traditional crystalline silicon and newer thin-film technologies), which ranged from 25 to 41 cents per kilowatt-hour in 2007, dropped to between 17 and 28 cents per kilowatt-hour by 2010. This continued the dramatic ten-year cost decline of solar energy. In terms of installation cost, the price per peak watt of power generated fell by nearly half in ten years, from an average of $9 in 2000 to $4.82 in 2010. By 2011, global installed pricing for solar PV systems dropped even further, to around $3.50. As in so many other industries, large-scale low-cost manufacturing in China and other Asian nations, combined with technology breakthroughs in the West and elsewhere, is accelerating this trend.

PV INSTALLED COST AND COST PER KWH: 2007–2020

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Year	Global Average Installed Cost ($/W)	LCOE (cents/kWh)	Global Average Installed Cost ($/W)	LCOE (cents/kWh)
2007	$7.20	33 – 41	$5.50	25 – 32
2008	$7.00	32 – 40	$5.10	25 – 30
2009	$5.35	25 – 31	$4.00	19 – 24
2010	$4.82	22 – 28	$3.60	17 – 21
2011e	$4.24	20 – 25	$3.19	15 – 19
2012e	$3.64	17 – 21	$2.92	14 – 18
2013e	$3.28	15 – 20	$2.68	13 – 16
2014e	$2.95	14 – 18	$2.47	12 – 15
2015e	$2.69	13 – 16	$2.27	11 –14
2016e	$2.44	12 – 15	$2.09	10 –13
2017e	$2.22	11 – 14	$1.92	9 –12
2018e	$2.02	10 – 13	$1.77	9 – 11
2019e	$1.84	9 – 12	$1.63	8 – 10
2020e	$1.68	8 – 11	$1.50	8 –10

Source: Clean Edge, Inc., 2011.

The director of GE's global research unit and the former head of its Power Systems group, Mark Little, predicted in a May 2011 interview with Bloomberg that solar may be cost-competitive with fossil fuel– and nuclear-generated power in three to five years. By 2020, Clean Edge, our clean-tech research and advisory firm, projects that solar prices will drop even more, making the cost of solar power about the same as or even lower than projected residential electric rates in more than 20 U.S. states. Innovative financing models, such as the no-money-down solar lease from SolarCity and other nationwide solar installers, have also helped make solar energy much more affordable for consumers and businesses.

Wind power is already considered the cheapest source of new generation in some regions of the U.S., averaging roughly 5 to 8 cents per kilowatt-hour nationwide in 2010, according to Clean Edge. All-electric vehicles, once prohibitively expensive (like the Tesla Motors Roadster, which debuted in 2007 with a sticker price of about $100,000), where available, are seeing the positive effect of increased competition. The Mitsubishi i, on the U.S. market in early 2012, listed for $27,990—more than $5,000 below the Nissan LEAF and just $20,240 after a buyer's federal tax credit. Falling prices are clearly key to the rapid adoption of all clean technologies, and we see every sign that these trends will continue.

"It's just like every other technology industry," says Alan Salzman, CEO and managing director of VantagePoint Capital Partners, a leading clean-tech VC firm in San Bruno, California, whose portfolio includes Bridgelux, Tesla, and utility-scale solar plant developer BrightSource Energy. "First you do it, and it's very expensive; the technology and the manufacturing economies of scale aren't idealized at all. Then the market develops, competitors come in, and prices fall. Three years after the Tesla, we had the Nissan LEAF at less than $35,000. Three years from now, we'll probably have Taiwanese all-electric cars on the market at fifteen grand."

The next force at play here is **Capital**. The growth in venture capital, as noted above, and other investment in clean tech have rebounded well since the 2008–09 global financial crisis. In 2011 alone, corporate and government global investment in and financing of clean energy was a record $260 billion—a nearly 40 percent increase from 2009, according to Bloomberg New Energy Finance (BNEF), a London- and New York–based financial research firm. Perhaps even more striking, the 2011 figure represents a fivefold increase in just seven years, from $52 billion in 2004.

But the biggest story of clean-tech capital in the past five years has been unprecedented levels of investment by national governments around the world. The U.S. played its part, with a roughly $90 billion injection in federal stimulus dollars (cash grants, loan guarantees, and other financing mechanisms) directed to domestic clean-energy companies and projects from 2009 through 2011.

As we will analyze in greater detail in the next chapter, however, the U.S. is just one part of a massive global influx of public money into the sector, including both stimulus and other programs. These include China (with up to $660 billion in government spending on clean energy in the next ten years), South Korea ($4 billion in 2011 alone, in a much smaller economy), Germany ($41.2 billion in 2010), and many other nations that have made clean tech a centerpiece of their present and future economic plans. This influx of private and public money is driving clean-energy growth around the world and rewriting the competitive rules of the global economy—the phenomenon that inspired us to write this book.

The third force is **Competition**. In the spring of 2006, we attended the first-ever Renewable Energy Finance Forum–China conference in Beijing. At the time, Chinese officials were just beginning to discuss their ambitious plans for clean-tech growth. In just six years, the nation's rise to the top of the industry has rendered moot our earlier distinction of China and Competition as separate global forces mov-

ing clean tech ahead. China is the world's number-one manufacturer of solar PV cells, the number-one market for wind power, and the largest producer and user of lithium-ion batteries (used in EVs and other clean-tech products), and it is at or close to the top in many other sectors. Although a wide range of nations in Europe, Asia, and North and South America have emerged as formidable competitors in different clean-tech sectors, China is quite clearly at the top of everyone's list.

As we will detail throughout the book, Competition refers not only to the battle for economic success among nations but to that among companies as well. In the U.S. clean-tech industry, China is on the minds of entrepreneurs, corporate executives, and financiers on a daily basis. And China's competitive challenge goes far beyond its attractive labor costs and strong government incentives for companies to locate there. It has become a fast-growing center of clean-tech R&D activity and innovation breakthroughs as well. In posing the all-important question of who will own the key technologies of the future, this last point may be the most critical factor in China's competitive favor.

It's not just China that's playing a central competitive role. As we'll explore in chapter 1, "The Global Landscape," a range of nations spanning four continents are all making clean tech a key focus of their global economic competitiveness. Competition also continues to drive clean-tech growth among regions, states, and cities. That is the focus of chapters 2 and 3, on the leading U.S. clean-tech states and cities, respectively.

As we noted in *The Clean Tech Revolution*, Competition also includes the increasingly critical factor of energy security. Given the interconnected global industry of oil in particular, the oft-cited target of true "energy independence" may be unrealistic for any country, and certainly for the U.S., in the foreseeable future. But the goal of reducing dependence on energy supplies that come from less-than-friendly

nations such as Iran, Libya, and Venezuela is certainly attainable, and it's a goal that the U.S., Germany, and dozens of other energy-hungry countries share.

Equally important in the U.S., the concept of energy security as a competitive driver of clean tech enjoys support among legislators and citizens of all political stripes. As we'll discuss in the climate section below, not all drivers of clean tech can make that claim. To attain the bipartisan support that will be necessary for making the policy changes that can turn the U.S. into a global clean-tech leader, the framing of clean energy as a matter of national security needs to be at the forefront of any conversation.

Next is **Consumers**. In the past five years, a wide range of clean-tech products and services have caught on with a broad swath of consumers worldwide. CFL bulbs (and, increasingly, LED lights) and other energy-efficient products populate the aisles and shelves of mainstream retailers like Walmart, Lowe's, and Home Depot. In January 2011, IKEA stopped selling incandescent bulbs at all of its stores in the U.S. and Canada. Viewers of San Francisco Giants baseball telecasts in Northern California see regular ads for local solar PV installer the Solar Company, with popular team broadcaster Duane Kuiper as the featured customer. And in a nice twist of irony, actor Larry Hagman, who portrayed one of America's most iconic (albeit fictional) oil barons, J. R. Ewing of the classic TV series *Dallas*, is now the official spokesman in the U.S. for German solar PV manufacturer SolarWorld.

Hagman lives in a fully solar-powered home in Southern California, but clean tech's consumer reach in the U.S. extends far beyond the traditional environmentally minded, early-adoption markets of the Pacific Coast and the Northeast. Arizona and North Dakota, for example, ranked in the top five states for most four-wheel passenger EVs registered per capita in 2010, and Virginia ranked number five in hybrids per capita. South Carolina, one of the nation's most politi-

cally conservative states, ranked number four in public EV-charging stations per capita as of March 2011. Texas, New Mexico, Wisconsin, and Utah are among the top ten states for the highest percentage of utility customers who choose to pay a small optional rate premium for a greener mix of electricity.

In the 21st century, however, the U.S. consumer market represents literally a tiny fraction of the overall picture. International commerce experts know, but many people are shocked to learn, that at least 95 percent of the world's consumers live outside the U.S. Not surprisingly, the meteoric rise of China's middle class leads the way. Credit Suisse predicts that China's consumer market will reach $16 trillion by 2020, surpassing the U.S. as the world's largest—with a projected 700 percent growth in per capita income from 2000 levels. To a somewhat less dramatic extent, this same expanding-consumer-class trend is playing out across India, Brazil, Indonesia, Vietnam, and many other rapidly developing nations. This global phenomenon, the so-called Base of the Pyramid market opportunity, has profound implications for the growth of the global clean-tech industry.

Over the next decade, these trends mean millions of new buyers of middle-class goods such as vehicles, homes, and appliances. In order to prevent massive increases in greenhouse-gas (GHG) emissions and other detrimental environmental impacts from this increased economic activity, those products will need to use significantly less energy than their historical predecessors in North America and Western Europe. Although this is admittedly a huge challenge, the market opportunity for global providers of energy-efficient products is enormous.

In the clean-transportation sector, for example, a Boston Consulting Group (BCG) study in July 2011 predicted that China will be the world's largest market for EVs by 2020, surpassing Europe and the U.S. The study found that about 13 percent of consumers in China say they are willing to pay a premium of $4,500 to $6,000 for a green

vehicle (EV or hybrid), compared with 9 percent of Europeans and just 6 percent of U.S. car buyers. BCG projects sales of five million EVs in China in 2020, up from just 2,000 in 2010. In India, pioneering EV manufacturer Mahindra Reva has opened more than 20 sales outlets for its small two-door, four-seat EV, considered the world's lowest-priced electric car, at $12,000. So while the U.S. consumer market remains critically important, clean-tech providers in the U.S. and elsewhere have great growth potential to tap the millions of current and new middle-class buyers living outside America's borders.

Next we have **Climate**. Although we believe that the evidence of increasing global climate change due to human activity is irrefutable, the political dynamics around the issue have changed dramatically since the publication of *The Clean Tech Revolution* in 2007. The earth's climate may be warming, but the political climate for a global agreement on reducing CO_2 emissions has definitely chilled. The list of setbacks includes the so-called Climategate controversy of 2009; very mixed results from carbon cap-and-trade systems in the European Union and elsewhere; the failure to reach meaningful global agreements at the United Nations international climate talks in Copenhagen in 2009, Cancún in 2010, and Durban in 2011; and, above all, the failure of the U.S. Congress to pass comprehensive climate legislation.

Quite frankly, we had an internal debate about whether Climate is still a significant driver of the global clean-tech industry in 2012. After considerable discussion, we concluded that the answer is yes—particularly outside the U.S. and in the private sector. The Kyoto Protocol, despite the absence of the top two greenhouse-gas-emitting nations (China and the U.S.) as signatories and Canada's withdrawal from the pact in late 2011, still requires nearly 40 of the world's largest industrial nations around the world to reduce their carbon emissions by the end of 2012.

Perhaps more important, the vast majority of the world's largest corporations, for a variety of reasons, care about carbon. In 2010, 409

of the S&P Global 500—and more than 3,000 companies overall—responded to the annual CO_2 emissions tracking survey of the Carbon Disclosure Project (CDP), a British nonprofit advised by PricewaterhouseCoopers. More than 550 institutional investors worldwide, managing more than $70 trillion in assets, use the CDP's data to help shape their investment decisions. And the fastest-growing area of CDP tracking is the GHG impact of corporate supply chains. Led by the pioneering work of Walmart and others in mandating sustainability initiatives among suppliers, the number of Global 500 companies reporting on their supply chains' carbon footprints doubled in just two years, to nearly 50 percent in 2010.

Those efforts drive the clean-tech industry forward in a myriad of ways, from McGraw-Hill's 14.1-megawatt solar power plant—the largest privately owned solar array in the Western Hemisphere—at its East Windsor, New Jersey, campus, to GE's plans to purchase 25,000 EVs for corporate fleet use by 2015. Despite political rhetoric and U.S. federal legislative inaction to the contrary, corporate efforts to reduce carbon emissions around the world are alive and well.

In terms of framing the political discussion, we find the debate moving beyond climate change per se to a much broader environmental impetus that embraces clean air, clean water, public health, and, of course, the main focus of this book: economic competitiveness and prosperity. If the moral imperative of "we must fight global warming" has become a political nonstarter, so be it. "Believe in climate change. Or don't. It doesn't matter," wrote renowned corporate sustainability consultant L. Hunter Lovins in her recent book with Boyd Cohen, *Climate Capitalism: Capitalism in the Age of Climate Change*. "But you'd better understand this: the best route to rebuilding our economy, our cities, and our job markets, as well as assuring national security, is doing precisely what you would do if you were scared to death about climate change."

We will delve more deeply into the political realities facing U.S.

federal, state, and local policymakers in chapter 5. But suffice it to say that the reduction of carbon emissions, whether by companies or countries, brings a huge range of desirable results that people across the political spectrum—and countries across the industrialized-nation/developing-nation divide at international climate talks—can agree on. Cleaner air for your children to breathe, cleaner water for your grandchildren to drink, a national energy supply that relies less on imports and creates more jobs at home—not even extremist politicians would argue against those benefits.

The final factor is **Connectivity**. History has seen many energy revolutions over the centuries, with the world moving from wood (and, for a time, whale oil) to coal, oil, natural gas, hydroelectric, and nuclear power as primary energy sources. But clean tech, which did not begin to coalesce as a high-profile global industry until the early 2000s, is the first energy revolution—and one of the first major nondigital industries—to grow up in the Internet era. Having seen this play out since the publication of our last book five years ago, we decided to add Connectivity (and the collaboration that it enables) as our sixth "C" driving clean-energy growth.

Some of the impacts of Connectivity on clean tech are obvious. The entire concept of the smart grid, for example, relies on high-speed and often wireless networks of information sharing to maximize efficiencies in the generation, distribution, and usage of electricity. Small wonder that so many giants of the high-tech and Internet industries, such as Cisco, Google, and IBM, are major players in smart grid (and have so many ex-employees starting and/or running smart-grid startups like Comverge, Silver Spring Networks, and Tendril). It's not unlike the large degree of cross-pollination between the semiconductor-chip and solar PV industries witnessed over the past decade.

But Connectivity as a driver of clean tech encompasses much more than just technologies and skill sets common to both industries. The capability of instantaneous collaboration across the globe—whether

by a Chicago-to-Guangzhou conference call on Skype, a new global market niche created by a Facebook page, or a computer-aided design updated simultaneously on four continents—is helping clean tech to grow on a daily basis. Clean-energy entrepreneurs out of MIT and Stanford are starting U.S.-based companies whose first customers are in India or Israel. Other startups like RelayRides (whose investors include Google Ventures) and Getaround essentially use Internet connectivity as their business model, connecting car owners and renters through a web page or iPhone/iPad app.

Collaborating with partners outside a company or organization is nothing new, of course, but many key players in clean tech are using today's high-speed-connectivity tools to bring inter-organizational collaboration to unprecedented new levels. Through the Open Architecture Network, created by San Francisco–based nonprofit Architecture for Humanity (AFH), more than 30,000 designers worldwide use tools like Autodesk's Freewheel to share 2-D and 3-D designs and ideas for low-cost, durable, energy-efficient homes and buildings in developing nations and disaster recovery areas. Launched in 2007 and renamed Worldchanging in 2011 after an AFH acquisition, the network had 6,500 projects in the design phase and more than 80 projects completed as of June 2011. "The Internet has created an incredible democratization of the architecture industry," AFH cofounder and CEO Cameron Sinclair said in a March 2011 interview with *The Atlantic*. "The realm of the pre-determined geniuses of the profession is no longer dictated by the number of inches in a broadsheet, an appearance on Charlie Rose, or the weight of a coffee table book. The Web has allowed us to act locally and act globally simultaneously."

But the most dramatic example of online, outside-the-company collaboration—true "crowdsourcing"—comes from GE's Ecomagination clean-tech initiative. Launched in July 2010, GE's $200 million Open Innovation Challenge invited companies, individuals—anyone—to submit ideas for business ventures in smart-grid technol-

ogies. Working with four leading clean-tech venture capital firms, GE has funded the best ideas and, in some cases, acquired the company outright, as it did with Ireland-based power-line-monitoring company FMC-Tech in May 2011. More than 90,000 people have participated in the Open Innovation Challenge—the largest corporate crowdsourcing effort in history. So far.

This trend will only accelerate. As members of the connected generation (so-called Generation Z) grow up, never knowing a world without instant global connectivity in the palm of their hand, online collaboration among companies, customers, partners, and even competitors will become the natural order of 21st-century business. Young people are generally much more comfortable sharing data, whether it's time-of-day electricity usage with their utility or ride-sharing plans with strangers—leading to greater efficiency, energy savings, and scores of clean-tech business ideas that no one has thought of yet.

The digital age of Connectivity will cause the transition to clean energy to occur much faster than the multiple decades or even centuries required by previous energy revolutions. It's a good thing, too, because due to resource constraints, climate concerns, population growth, and a range of other global challenges, the world can't wait that long. And in global competition, the need for speed by industries that traditionally have moved very slowly—notably energy, utilities, and automotive—has never been greater.

Not that these and other large global industries, with their massive physical infrastructures, regulatory constraints, and often well-entrenched business processes, will ever move or change at cyberspeed. And the new world of Connectivity also brings new security challenges. More sophisticated online applications seem to bring ever more sophisticated cyber-attacks, such as the Stuxnet computer worm that infected computers at an Iranian nuclear power plant in 2010. Global energy transitions are not seamless; plenty of old and new obstacles stand in the way. But we still believe that Connectivity,

along with the other five C's, will make the transition to clean energy occur faster than the energy revolutions of the past.

THE CHALLENGE AHEAD

As the 21st century moves through its second decade, these six powerful global forces will continue to accelerate clean-tech development, deployment, and growth around the world—and make clean tech the most vital competitive industry of our time. The U.S. can play a leading role in this industry—as it did in the earlier technology revolutions of computing, telecommunications, and the Internet—but currently, it is falling behind.

What can and should be done? In this book, we'll show that while the challenge is great, the U.S. can absolutely meet it. We also recognize that in today's interconnected global economy, competition among nations is not a zero-sum game. In many cases, collaborative approaches that create clean-tech jobs and grow businesses in both Ohio and China, say, are the best strategy to pursue. What we don't want to see is the U.S. falling behind a large contingent of other nations in the race to own the key technologies of this century and to, in President Obama's words, "win the future." Yet that is precisely what we see happening without the important policy and business-strategy corrections that we'll detail in the rest of this book.

First, in chapter 1, on the global landscape, we'll discuss the major developments and commitments to date that have made nations such as China, Germany, Japan, and Brazil formidable competitors and/or leaders in various aspects of clean tech. In the next two chapters we'll return to the U.S., showing why—so far—certain American states and cities have been where the clean-tech action is in our nation. Chapter 2 will spotlight the top ten U.S. states for clean-energy technology, policy, and capital, as ranked by Clean Edge's *State Clean Energy Leadership Index*, extracting the most important lessons for growing

a clean-energy economy at the state level. Going beyond public policy, this chapter will also list the top five clean-tech companies to watch in each leading state.

Chapter 3 will present the top 15 U.S. cities for clean-tech jobs, from building-energy-efficiency specialists in New York City to solar-cell-manufacturing technicians in Portland, Oregon. This chapter draws on the latest research from Clean Edge and other globally recognized sources of data and analysis from this rapidly emerging jobs sector. As with the states, we'll examine the mix of assets in technology, policy, and both financial and human/intellectual capital that makes these cities leaders in clean-tech employment and economic growth.

In chapter 4 we'll return to a global view, identifying the four biggest clean-tech developments reshaping the world's power-grid, transportation, and energy systems. That will lay the groundwork for chapter 5, "The Clean Tech Imperative," where we take a hard look at the new rules of global economic competition in the 21st century—and drive home the case that the clean-tech industry is vital to our economic future. We'll also examine the political realities of Capitol Hill, K Street, and elsewhere that present formidable—but not insurmountable—hurdles to enacting key federal clean-energy policies. We'll take a look back at history to show how America has successfully met such transformational challenges in the past: with its manufacturing effort in World War II, the development of ARPANET (the precursor to today's Internet), and the Apollo space program. And we'll briefly profile 20 American leaders we call the Transformers: the top business, political, educational, and other luminaries—including many who have moved into clean tech from other fields—who are striving to make the U.S. clean-tech industry competitive with any in the world.

The book's concluding chapter is a Seven-Point Action Plan—covering both the public and private sectors—which presents a blueprint for U.S. leadership in the global clean-tech industry. Ambitious but realistic, the plan includes recommendations for government

policy, business strategy, financial investment, education, and other areas to supercharge our efforts in clean energy, clean transportation, energy efficiency, smart grid, green building, and other critical clean-tech sectors.

Many experts and participants in the clean-tech industry are saying that the race for global supremacy is already over, with China sure to expand its overall lead, Germany to continue as the world's largest solar energy market, and a future certain to erode America's competitive standing in clean tech in the same way it has been damaged in other industries. We do not agree. We believe that the U.S. can leverage its unparalleled assets—among them great research universities, the world's best entrepreneurs, a culture of innovation, a robust network of venture capital, and strong patent-protection laws—to lead this dynamic, game-changing industry. We do not minimize the scope of that challenge. But with some new directions in policy, business, and above all, thinking, we are absolutely convinced that the U.S. of the 21st century can be the world's leading Clean Tech Nation.