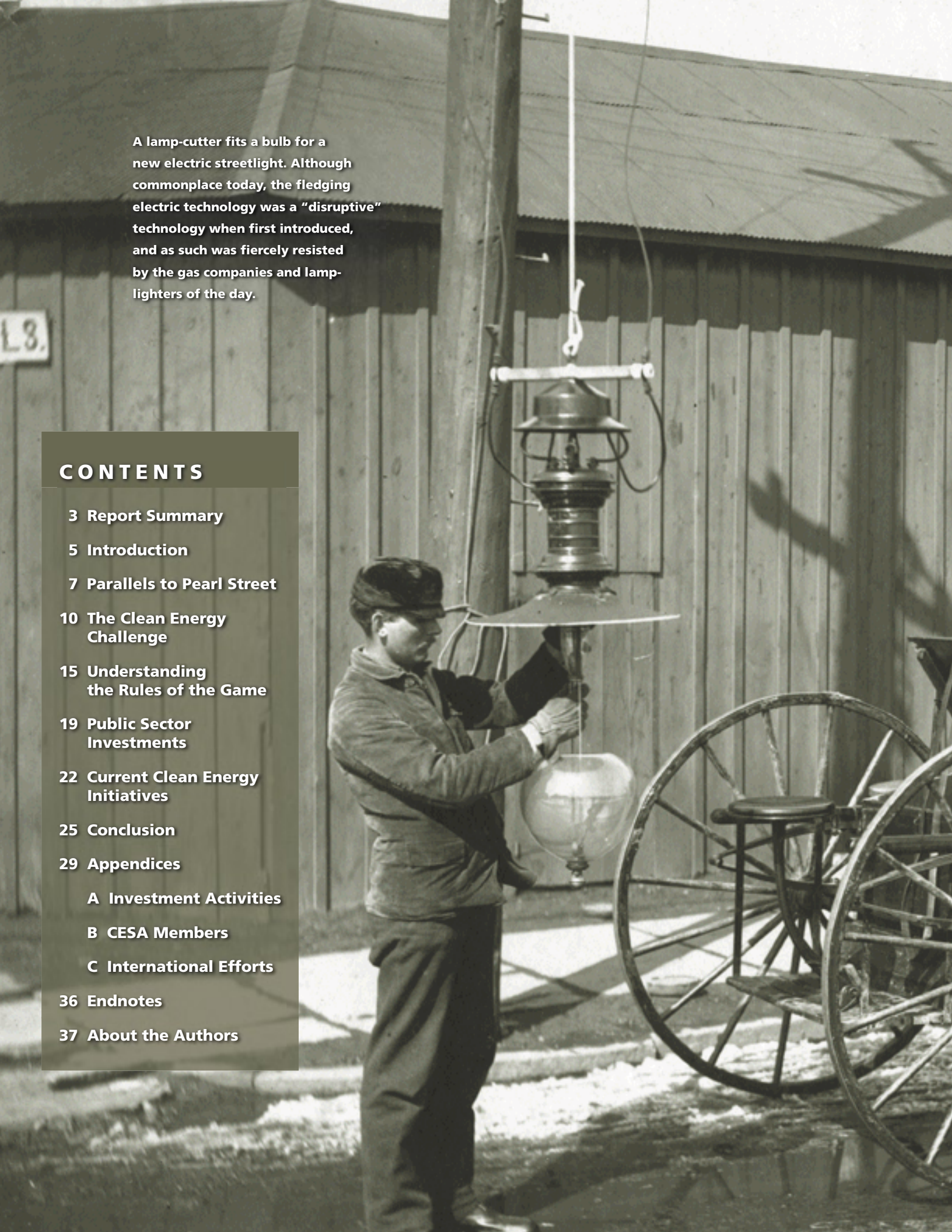
CleanEnergyGroup

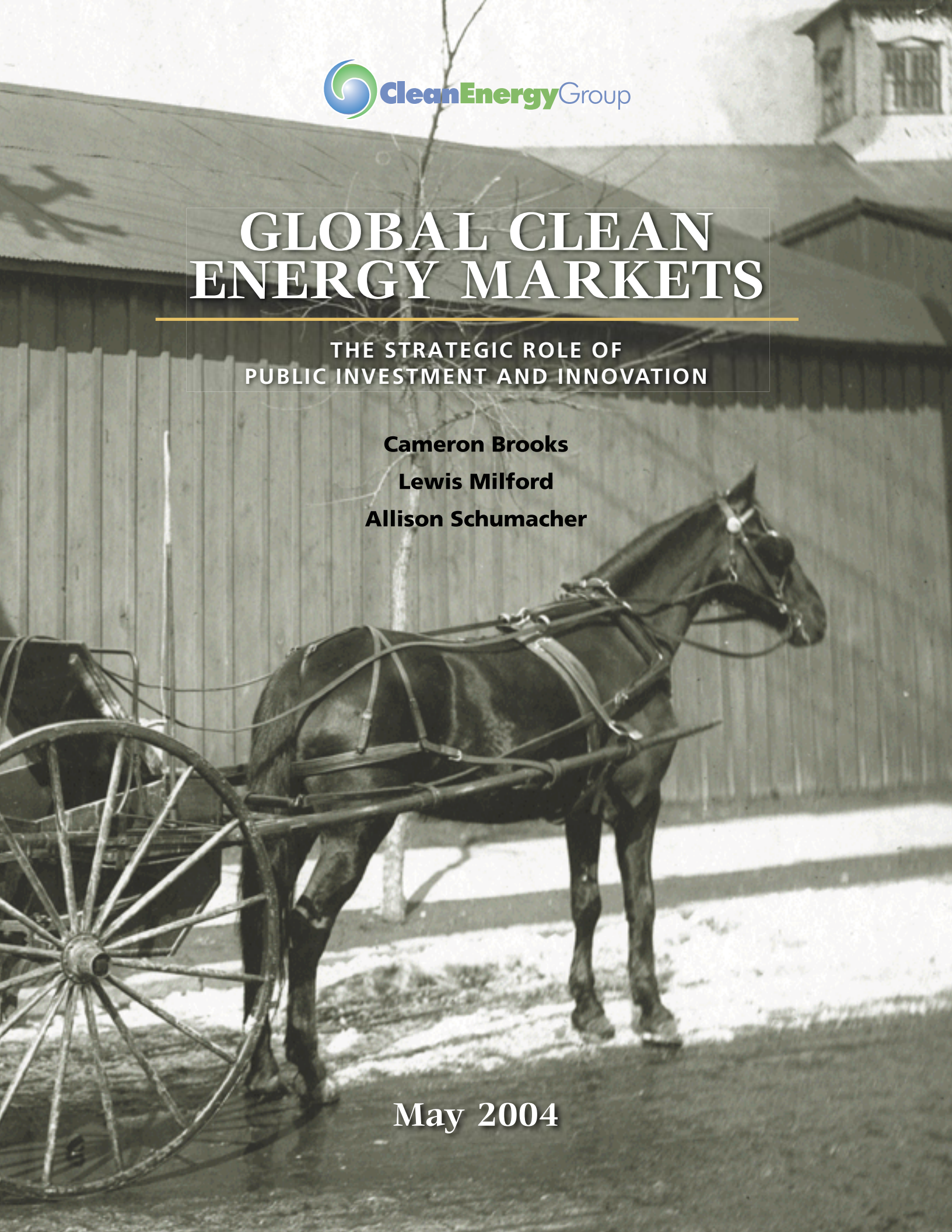
GLOBAL CLEAN ENERGY MARKETS

THE STRATEGIC ROLE OF PUBLIC INVESTMENT AND INNOVATION



A lamp-cutter fits a bulb for a new electric streetlight. Although commonplace today, the fledging electric technology was a "disruptive" technology when first introduced, and as such was fiercely resisted by the gas companies and lamp-lighters of the day.

CONTENTS



GLOBAL CLEAN ENERGY MARKETS

THE STRATEGIC ROLE OF PUBLIC INVESTMENT AND INNOVATION

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May 2004

Thomas Edison reenacts the construction of his first incandescent bulb, initially tested in 1879. His experiences and strategies for introducing electricity hold insights deeply relevant to those working today to introduce new clean energy technologies. Although higher-priced than the gas lighting of its day, electric lights offered attributes such as safety, theatricality and flexibility that drove its early adoption.

REPORT SUMMARY

This report examines the role of public investment and technology innovation to build global clean energy markets. A shift to clean energy technology is needed to address growing environmental, economic and energy problems of the 21st century. Clean Energy Group (CEG) invites interested parties to work together with us to meet these challenges.

Currently, efforts to achieve wide-scale implementation of clean energy technologies face formidable barriers, including:

- Fragmented and immature markets
- Unorganized investment patterns
- Public credibility gaps
- Unreliable market estimates
- Regulatory uncertainties

While considerable, these market challenges are not unique. This report identifies innovative new strategies to address these challenges, drawing upon:

Historical parallels. Electrification, as promoted by Thomas Edison, stands as the prototypical energy innovation and a classic battle between fledgling upstart and powerful incumbent. His successful strategy relied on mimicking existing technologies, promoting side-by-side investments and recognizing long transition timeframes.

Contemporary business models. Business scholars and strategists have a sophisticated understanding of how to successfully introduce disruptive technologies. Applying these compelling theories to the clean energy challenge reveals the misleading emphasis on cost and resource scarcity; the importance of exploiting niche markets; and the ability of social networks to accelerate technological change.

Public sector investment. The public sector has played a critical role in the development of infrastructure from railroads and the telegraph to highways and the internet. Today, a new breed of public investors is targeting gaps and inefficiencies in the innovation chain and seeking collaboration with the private sector. Also, clean energy is a new driver of economic development, and a major investment opportunity.

Recommendations for moving forward. This report describes a framework for moving forward based on these findings. This framework proposes a domestic and international collaboration among public clean energy funds, project developers, venture funds and institutional investors to build global clean energy markets.

We recommend increasing joint activity among these players in order to:

1. Develop global networks of clean energy practitioners
2. Understand processes of technology innovation for clean energy
3. Organize federal, state, international and private sector activities to create complementary and synergistic relationships
4. Create new public and private funding streams and investment vehicles

Preface
Innovation as Social Evolution

For every technological revolution, there are two stories: one unfolds on stage, the other in back. The on-stage stories celebrate the individuals and inventions that changed the world—how James Watt's steam engine powered the industrial revolution; how Thomas Edison's light bulb sparked the electric age; how Henry Ford's mass production built the modern world. These are the stories any schoolboy knows and yet they are, if not outright wrong, dangerous simplifications. The backstage stories, by contrast, reveal a more complex yet also more manageable process. In each case, the innovation process depended more on technological and social evolution rather than revolution and more on the actions of communities rather than individuals.

CEG's report demonstrates the value of recognizing this backstage process, and of finding in it the lessons for leading today's clean energy revolution. As the authors point out, this revolution will come not from individual inventors but from the combined and coordinated efforts of scientists, investors, and entrepreneurs working together to build new clean energy ventures capable of first co-existing with, and ultimately displacing, the existing energy infrastructure.

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INTRODUCTION

Our energy future is not predetermined. A new generation of power plants exists—plants that are cleaner, smaller, and can be located near the end-user. The social, financial and policy decisions we make today will determine if cleaner energy technologies, such as wind, solar and fuel cells, become mainstream energy sources in the future. If they do, a revolution will occur that will be every bit as dramatic as the one credited to Thomas Edison over a century ago.

His electrification of society is the prototypical example of successful innovation. Electricity is now so pervasive and commonplace as to seem dull. Yet in Edison's time, efforts to bring it to market were fiercely contested by an entrenched gas industry that mobilized its political power and economic heft against his new venture.

That technology transformation, like many others, contains lessons for the historic challenge of our time. In important ways, Edison's market experiences reveal patterns which we should expect clean energy technologies to follow. First, technology transitions are never as obvious beforehand as in hindsight. Second, history shows that these technology transitions take time, usually several decades. Third, they begin with a whisper, not a bang, by imitating existing technologies.

We can expect that clean energy will face many of these same difficulties, as well as the same opportunities for enormous social and environmental change. But this time, we know more about how to accelerate technological change and public agencies have organized with missions to promote clean energy commercialization.

New public clean energy funds, both in the United States and abroad, are working to accelerate the commercial application of low-carbon power technologies. By targeting the gaps between technology creation and real markets, the funds have become new models for public sector investment. Along with these public investment dollars, hundreds of billions of dollars of private capital also will be invested in the coming decades to upgrade and expand our energy infrastructure; already, private venture firms and pension funds have started to target clean energy for investment.

To realize the full potential of clean energy, we must do more to coordinate these emerging forces. We need to concentrate strategically the best minds in business, finance and government to mobilize the capital needed in order to grow nascent clean power efforts to a global scale.

To succeed, we must understand the drivers behind technological innovation and align public investment with these trends. We need to act quickly, wisely and humbly. Through alliances in the United States and internationally, we have begun some of these initiatives. At this historic and critical juncture, Clean Energy Group invites you to join with us to meet these challenges with greater knowledge and strategic collaborations to promote the clean energy transition that is so important to our future.

In important ways, Edison's market experience reveals patterns which we should expect clean energy technologies to follow.

In order to leave a legacy for the next generation worthy of our abilities, we need to generate billions of dollars of new public and private investment in clean energy technologies. A key assumption of this report is that a more thoughtful and widespread engagement on innovation approaches and opportunities is needed to attract new capital to this sector.

PARALLELS TO PEARL STREET

Although optically the most successful light that has been presented in the long history of illumination, the incandescent system as yet promises not such financial success as will lead to its general adoption."

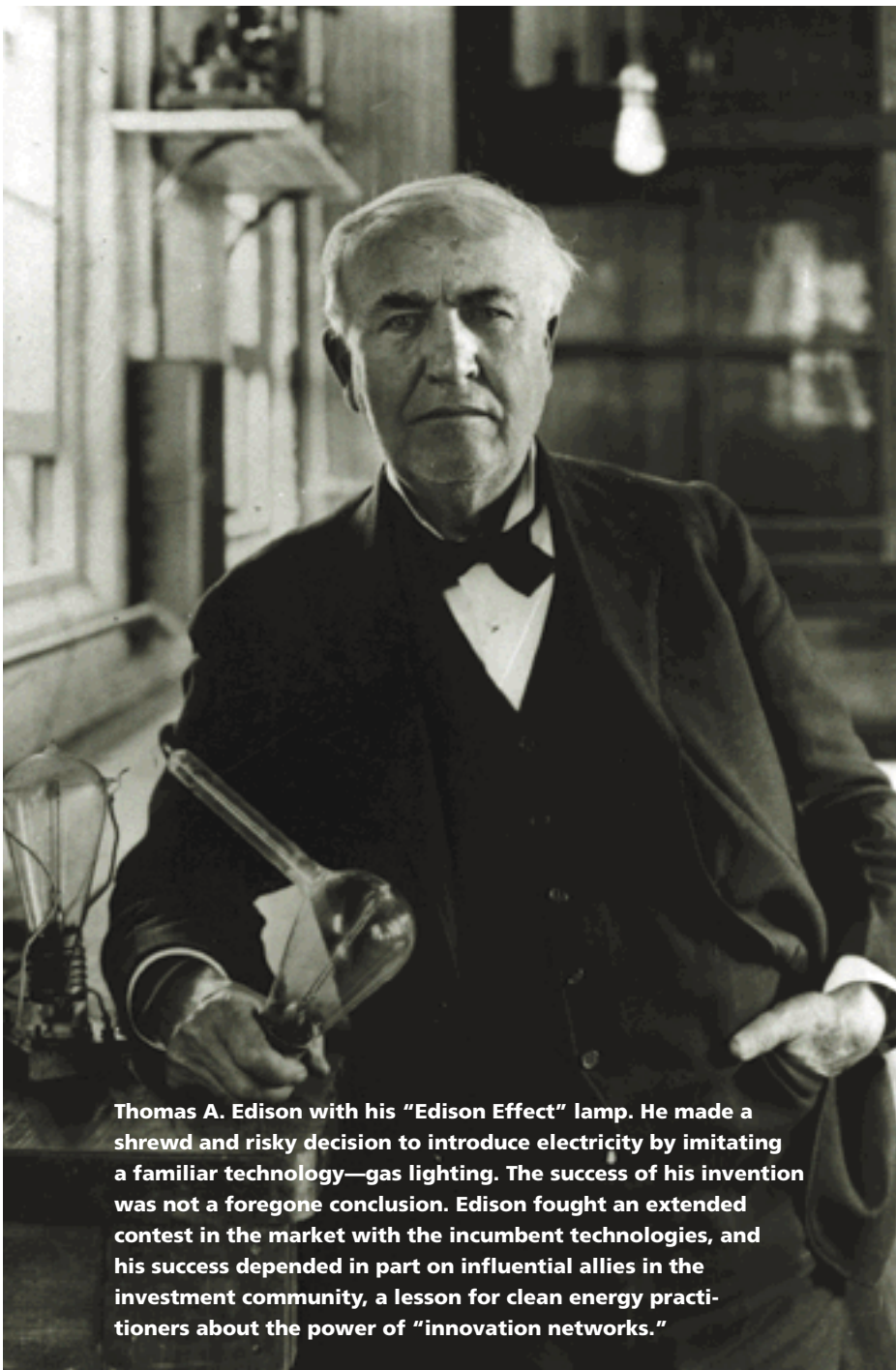
— NEW YORK TIMES, SEPTEMBER 10, 1882

The *Times'* observation about Edison's new light bulb, read with over a century of hindsight, seems quite comical. Just the week before, Thomas Edison's Pearl Street station had begun selling electricity to 25 buildings in New York City's financial district, illuminating 400 lights for 85 customers.[1]

From our modern vantage, where a lumen of electric light in the United States today costs less than 1/1,000th of Edison's then new, high-priced electricity, there is a sense of inevitability that his technology would have exploded from this tiny base to become the life blood of our industrial economy.[2]

But in the 1880s, electric light was an unproven technology with many critics. In London, where Edison also opened a power station, the British House of Commons heard testimony that there was not "the slightest chance" that electricity could be "competing, in a general way, with gas."[3]

The same cynicism greeted him in America. By the time Edison's electric light was introduced in the US, gas companies had sunk nearly $1.5 billion of capital investments into the plants and pipes which lit the nation's homes and offices. For nearly fifty years, gas lamps had been the light of choice, displacing candles and whale oil. The industry's influence was inextricably



Thomas A. Edison with his "Edison Effect" lamp. He made a shrewd and risky decision to introduce electricity by imitating a familiar technology—gas lighting. The success of his invention was not a foregone conclusion. Edison fought an extended contest in the market with the incumbent technologies, and his success depended in part on influential allies in the investment community, a lesson for clean energy practitioners about the power of "innovation networks."

linked to the physical, economic and political infrastructure of the city. Gas companies controlled exclusive rights to bury underground lines. The street lamps were lit every night by a cadre of city employees. Each gas company was awarded an exclusive service territory, and their handsome monopoly profits commanded strong influence with the political machine of Tammany Hall.

It is odd to think that the most pervasive technological innovation of the last century—electrification—was widely derided as too expensive and attacked by the political and economic might of the entrenched gas industry.

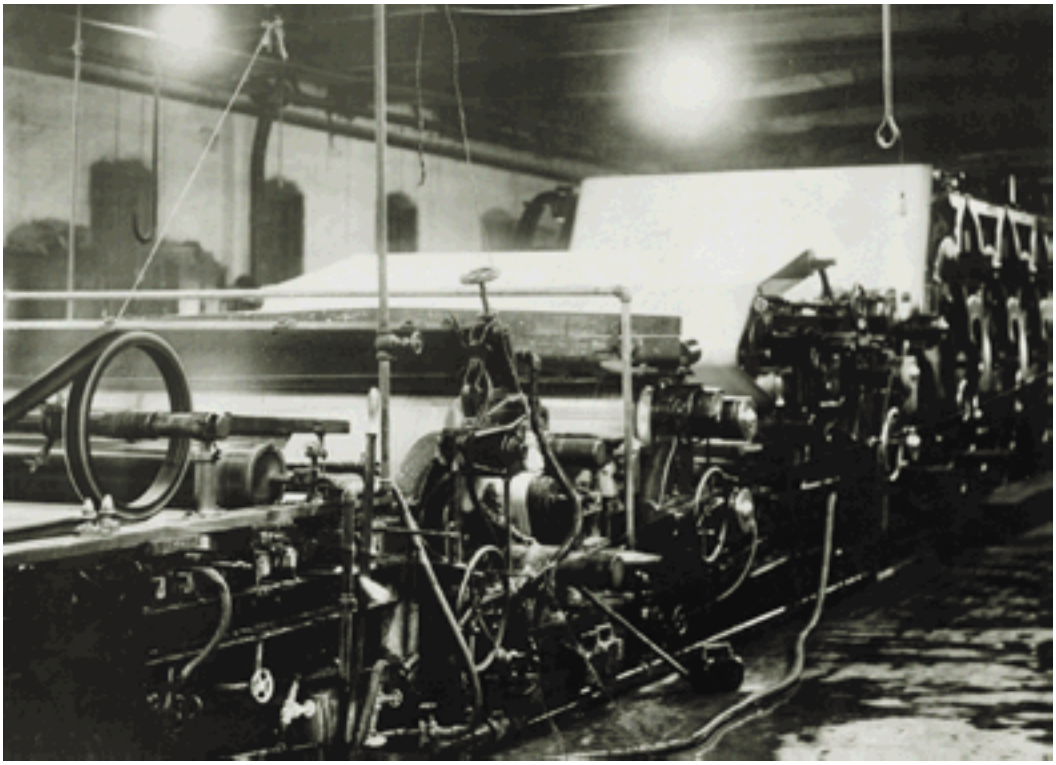
Edison's new venture was quickly set upon. The Mayor of New York flatly rejected the first application for an operating license. Only pressure from Edison's backers, which included J.P. Morgan, was able to overturn the decision. The city aldermen next proposed a fee of $1,000 per mile of copper wire and 3% of gross receipts. In contrast, gas companies were granted free access to install mains and paid only property taxes. With their major investments in infrastructure long since recovered, the gas companies could comfortably charge their customers much less.[4]

It is odd to think that the most pervasive technological innovation of the last century—electrification—was widely derided as too expensive and attacked by the political and economic might of the entrenched gas industry. What is commonly perceived as a simple process of technological progress advancing beyond an inferior product was, in fact, a classic battle between upstart and incumbent, which holds insights relevant in today's markets.

A first insight is revealed through Edison's choice to introduce electricity incrementally, first as a source of lighting. The *New York Times* article notes that the incandescent bulb could not compete with the cost of gas, a fact which "Mr. Edison has repeatedly acknowledged." Edison saw a big market for electricity to power motors and other devices, which would create demand over a longer period of the day. To gain market share and acceptance, Edison sold electric lighting at a loss that was subsidized by his more lucrative sales of electricity to power motors and new appliances.[5] He shrewdly marketed electricity for light, but knew the larger markets would be the sale of power to the industrial engines of the future.

Distributed generation technologies, such as fuel cells, promise to deliver highly reliable power to end-use customers. As Edison's innovation revolutionized the design of factories and homes, these new technologies can revolutionize the design and operation of our current centrally distributed power infrastructure.

Photo: Fuel Cell Energy



It took many decades, well into the 2oth century, for electricity to be widely adopted by industry. Industries that needed to meet growing power demands, such as paper manufacturing shown here, installed electricity alongside other, existing power sources. Exactly this kind of parallel investment scenario is likely to occur with clean, distributed technologies in the near future.

A second insight has to do with the likely pace of technology adoption—the great electric transformation took decades to complete. By 1900, nearly twenty years after the opening of the Pearl Street Station, electric lights were found in less than 3% of US homes[6] and electric motors made up less than 5% of the nation's industrial power.[7] Because firms were reluctant to retire productive equipment, new electric motors had a low adoption level. Not until the 1930s did electricity account for over 80% of the installed mechanical capacity in the country.

The adoption of electricity was driven by growing industries such as automobile manufacturing in the 1910s and paper production in the 1920s where electricity did not immediately replace existing, but expanded total, power capacity. Ultimately, the greatest change was the wholesale reengineering of lines of production to exploit the capabilities of the new technology.[8]

Today, advocates of clean power face many of the same innovation challenges that Edison saw and met—how to commercialize a new technology in the face of an abundant and cheap resource sold by powerful incumbents? The challenge requires simultaneously subverting the existing status quo while establishing new standards, expectations of performance, and markets for the new technologies. A transition to clean energy technologies requires educated approaches that help overcome the inherent uncertainties of the new technologies, preparations for a long transition timeframe, and strategies to increase the speed and efficacy of displacement.

But in today's power market, the difficulties with technology turnover may be lessened somewhat by the emerging role of public investing in clean energy markets. We are presented with an imperative to seek a low-carbon energy regime unlike anything faced by Thomas Edison, but we also have some new tools at our disposal to meet that challenge.

THE CLEAN ENERGY CHALLENGE

Smart investors are moving now to learn more about the nexus between environment and capital, and to avail themselves of the expanding opportunities in this realm.... The time has come for those of us who are investment leaders to open the doors to a new era of smart environmental investment."

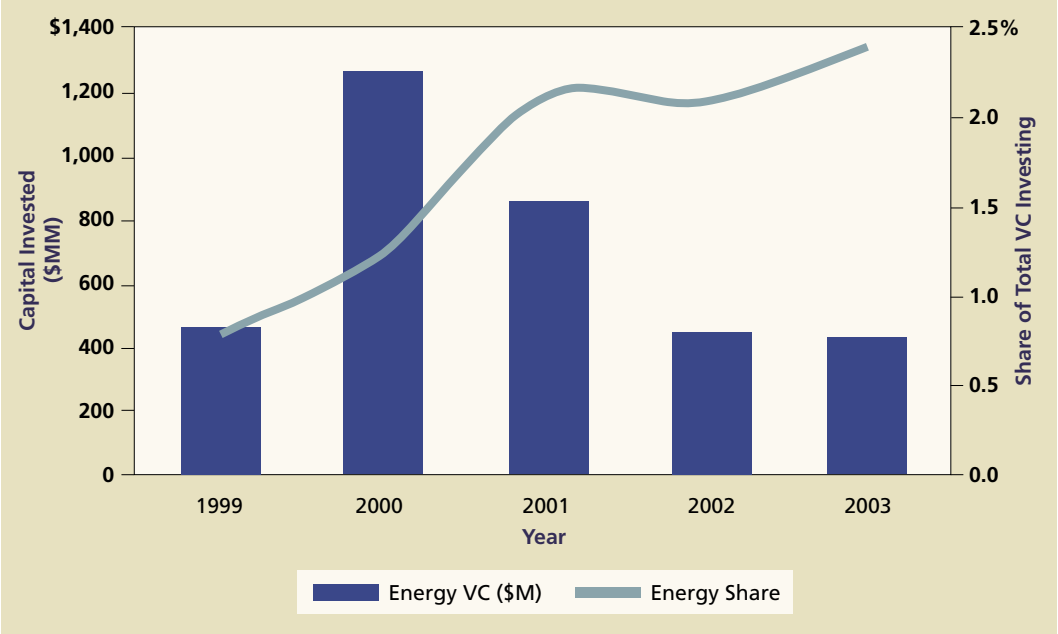
– CALIFORNIA TREASURER PHIL ANGELIDES[9]
NOVEMBER 21, 2003

Staggering amounts of new power sources will be required in the decades ahead to meet global electricity demand, but it is far from certain that clean energy technologies will be a major part of that mix.

The International Energy Agency recently estimated that electricity demand worldwide will double by the year 2030. Over 1000 GW of existing plants will be retired and replaced, while over 3500 GW of new capacity will be added. If these predictions prove correct, this means that in the coming few decades, construction of new and replacement power plants will bring an increase of 130% over current capacity of approximately 3500 GW (the current worldwide production).

The Long Island Power Authority's Clean Energy Initiative helped finance this commercial rooftop photovoltaic system.

Energy-Related Venture Capital Investments



Source: Nth Power

New power will be needed and new plants will be built. The question is, "What part will clean energy technologies play to meet this new demand?"

In other words, we could build as much generating capacity in the next 20–30 years as we did in the entire previous century, representing a total investment of nearly $10 trillion. The annual investment required is equivalent to about 1% of global GDP.[10]

Inevitably, fossil fuel and nuclear power plants will get their share, bolstered by favorable subsidy, tax and regulatory policies. And some of this new capacity probably will prove to be unneeded, with efficiency reducing overall demand. But new power will be needed and new plants will be built. The question is, "What part will clean energy technologies play to meet this new demand?"

Decades of research and development advances, driven largely by government investments, have led to a proliferation of new technologies for clean power.[11] Capacities that were once measured in kilowatts are today measured in megawatts. Recent growth rates of over 20% per year are common in the wind and photovoltaics industries. Fuel cells are providing reliable, high-quality power for critical facilities. For example, few people know that during the August 2003 blackout in New York City, one police station was able to keep its lights on powered by a fuel cell.

While the trends are encouraging, the scale remains comparatively small. Solar and wind power in the last five years have surged with over 30% annual growth but still represent less than 1% of global electricity generation.[12] Including small-scale hydroelectric and fuel cells, the overall figure for clean energy today is between 3–4% of total electric generation in the US. A clean energy future is far from certain.

Some analysts might suggest that the "decarbonization" of electricity is an inevitable historical trend. As the *Economist* notes, "As societies have grown wealthier, they have been shifting from dirty solid fuels with a high carbon content to liquid hydro-

carbon fuels with a lower carbon content, and ultimately to clean-burning gases."[13] This trend suggests to some that a true "business-as-usual" scenario does not continue the energy regime of today, but will follow historical trends and eliminate carbon from our energy supplies by the end of this century.[14]

Without questioning the trend, the countervailing view concerns time. Data suggest that relying solely on the inevitability of this historical trend may be "dysfunctional at best, suicidal at worst, and certainly will prove environmentally and economically ruinous at some point." Extrapolations from estimates of the Intergovernmental Panel on Climate Change (IPCC) suggest that we can "afford" to burn less than 10% of the current reserves of coal, oil and gas. [15] Further studies conclude that substantial reductions must occur within the next 10 years or it may be "nearly impossible" to achieve meaningfully reduced carbon dioxide concentration levels.[16]

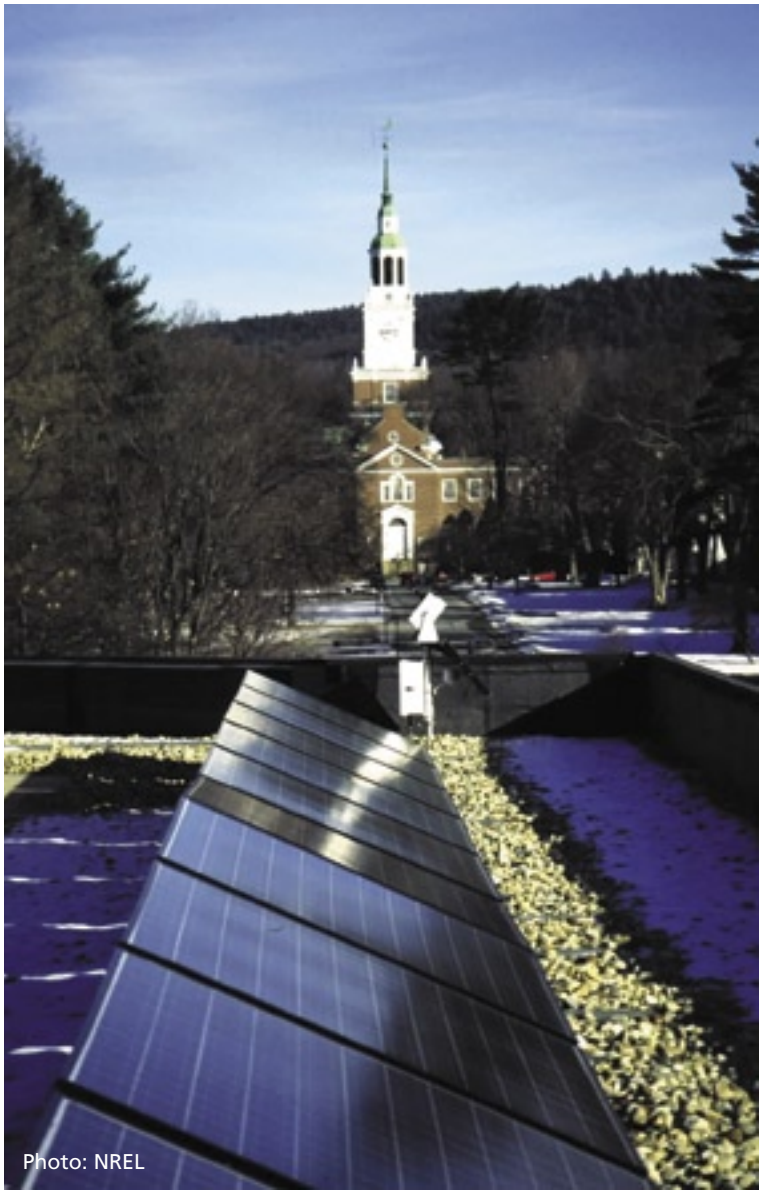


Photo: NREL

Many US states have wisely created clean energy funding mechanisms to spur clean energy innovation and new markets.

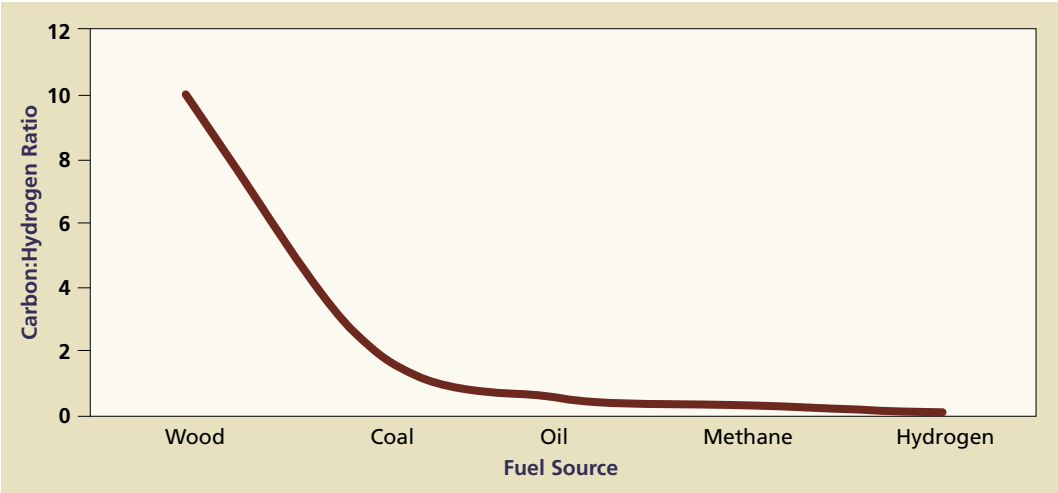
In short, climate change demands that we accelerate the historical drive toward decarbonization.

Current trends in clean energy development in the United States, with only a few exceptions, suggest the strong persistence of barriers to widespread implementation. For the most part, these are market and regulatory barriers—not technical ones.

Under the current policy regime, renewable energy, especially central generation wind and similar technologies, is particularly dependent on policy support and public funding. This is not an inherent characteristic of the technologies themselves, but a result of how the policies and regulations have developed over time. In many cases, historical regulatory structures that protect the ongoing power of utilities combine to thwart the growth of the clean, distributed energy industry.

Exacerbating this regulatory uncertainty, the markets for clean energy are new and relatively immature. In this environment, information gaps and high transaction

Relative Carbon Content



Source: Ausubel, 2004

Climate change demands that we accelerate the historical drive toward decarbonization.

costs create new risks for investors, often leading them to adopt a "wait-and-see" approach. In recent years, capital from conventional energy investors has been largely absorbed to fund attractively priced transfers of existing assets.

The philanthropic community faces financial constraints, limiting its ability to spur change in this area. And, although climate change concerns are growing, in the United States international greenhouse gas agreements cannot yet be considered substantial market drivers. Finally, clean energy technologies, despite their advances and growth, still face an enormous "credibility gap" in public opinion.[17]

On the positive side, clean energy is increasingly being targeted as a large market growth opportunity over the next decade both in the US and in Europe. Some industry analysts conclude that clean energy could be the most significant growth sector in the medium term for US and European generation and energy investment markets, increasing several times faster than the fossil fuel sector and proving cost-competitive, without subsidies, in the next decade. Annual US installations of renewable energy are expected to increase by a factor of five in the next ten years, reaching 4,000 MW of new capacity annually.[18]

These prospects for growth are attracting new private investment capital. Venture firms, pension funds and other private investors have begun to explore ways to expand the pool of public and private capital devoted to clean energy. $428 million was invested in US energy technology companies from venture capital funds, increasing its share of all VC investing to 2.4% for 2003.[19] The California Treasurer recently proposed plans for the state's two largest pension funds to invest $1.5 billion in clean technologies, including the creation of a $500 million fund for venture capital, private equity and project finance.

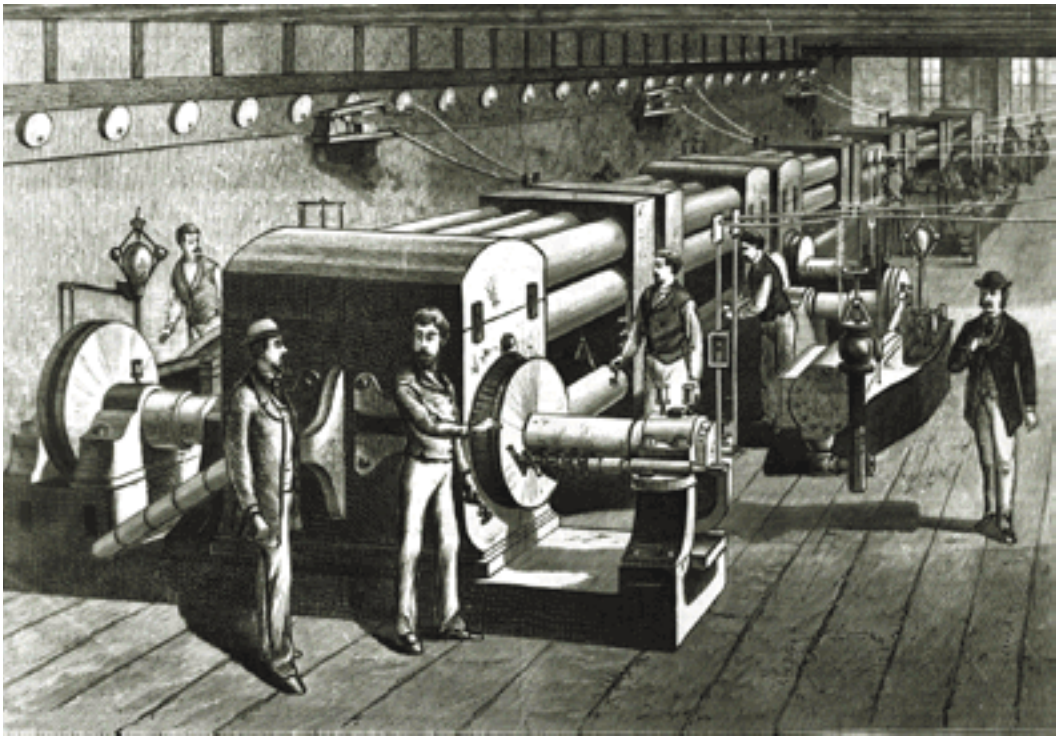
Power reliability is one key driver of this renewed investor interest. "Trees or terrorists, the power grid will go down again," concluded a recent *Economist* article that also observed the August 2003 blackout in North America cost power users about $7 billion.[20] Economic and political security is also driving interest to fund more depend-

able domestic sources of supply and to keep dollars invested at home.

Getting to scale is the key to success. Enormous amounts of public and private capital will be spent on new power sources. Ultimately, the issue is a social question—what part of new investment will be used for clean energy? The answer will depend, in large part, on the desire and ability of the public sector to attract private investment through favorable investment and regulatory decisions.

A key question is whether it is possible to accelerate technology transition in order to leapfrog another wave of fossil-based power and usher in a new low-carbon economy.

A key question is whether it is possible to accelerate technology transition in order to leapfrog another wave of fossil-based power and usher in a new low-carbon economy. While uncertainties will remain about which clean energy market segments are most likely to achieve the most rapid growth and in which time frames, it is clear that this market shift will require significant new flows of investment capital to support the development of new projects and companies. Public funding has an important role to play to bring about this change.[21]



An artist's sketch of the original Pearl Street Generating Station, opened in 1882. The first electric generating station was panned as an investment by *The New York Times*. Twenty years after electricity was being generated, a mere 3% of the population was served by electricity. It took almost 50 years for this "new" technology to be in widespread use.

UNDERSTANDING THE RULES OF THE GAME

The ancients who attempted to fly by strapping feathered wings to their arms and flapping with all their might as they leapt from high places invariably failed. Despite their dream and hard work, they were fighting against some very powerful forces of nature. Flight became possible only after people came to understand the relevant natural laws and principles that defined how the world worked..... As in the analogy to manned flight, these laws (of disruptive technologies) are so strong that managers who ignore or fight them are nearly powerless to pilot their companies through a disruptive technology storm."[22]

— HARVARD BUSINESS SCHOOL PROFESSOR CLAYTON CHRISTENSEN

It should come as no surprise that there are specific "rules of nature" that govern how a technological discovery advances from "invention" to "innovation." Nor should it come as a surprise by now that novel innovations do not automatically become diffused throughout society.

The barriers now facing clean energy are not unique. The widespread changes that have swept through the power industry at other times have each faced similar barriers: high cost; an abundant existing resource; politically powerful, entrenched incumbent players; and, long lag times for adoption. The new technologies that disrupted the previously established regime were successful because they were aggressively promoted for their abilities to precisely satisfy the changing demands of customers in the marketplace.

The success of electricity in the early part of the twentieth century is held up as an icon of invention and technological innovation. However, as we report here, it was hardly a simple story of "one innovation's demonstrable technical and economic superiority over an incumbent rival."[23] Early electric light was more expensive than the alternatives of gas or kerosene. It was not truly cost competitive until well into the 20th century.[24] To some, Edison's choice to develop a central generating station was "an invitation to throw money down a rathole."[25]

The recognition that energy transitions in the past have overcome similar barriers to those facing clean energy today is a heartening insight. However, it does not offer a specific, short-term roadmap for how to achieve transformation to a clean energy world.

An advantage we have today, which Edison did not enjoy, is access to leading scholars who have spent their careers divining the ways that companies develop and deploy "disruptive" technologies—those that upset the technology status quo. But these approaches have never been system-

The new technologies that disrupted the previously established regime were successful because they were aggressively promoted for their abilities to precisely satisfy the changing demands of customers in the marketplace.

"What wind turbines really produce are jobs," suggest many recent studies on the economic development impacts of clean energy technologies. A study commissioned in Pennsylvania concluded that renewable energy development would lead to the creation of 85,000 new jobs and $2.8 billion in new earnings over a 20 year period.

atically applied to the challenge of clean energy. Yet, their strategic insights offer new 21st century business models that are needed to accelerate the commercialization of clean energy technologies, such as wind, solar, fuel cells and hydrogen fuels. And, in turn, public investors are starting to recognize these perspectives as valuable guideposts to their role.

Harvard Business School Professor Clayton Christensen, author of the best selling business books, *The Innovator's Dilemma* and *The Innovator's Solution*, and the leading architect of "disruptive technology" theories, describes the challenge facing new innovations. According to him, the "most common misconception about disruptive innovation is that the disruption is caused purely by the technology. Characteristics such as features and functionality are certainly important. But it's the business model—the pricing, cost structure, sales process, and so on—used to commercialize the technology that's truly critical."[26]

Again, history provides a guide. At the end of the last century, a lawyer for the predecessors of the General Electric Company described the challenge of "market creation." Electricity "was new and presented problems which were substantially without precedent and which required new methods. People did not at all appreciate the need or value of electricity. They had to be educated to its use.... Suitable manufacturing methods as well as adequate ways of distributing the manufactured product had to be devised.... Customers did not exist; they had to be created."[27]

One historian who has chronicled the origins of the electric industry wrote, "Although today we consider electric lighting a necessity, we must remember that there was no obvious need for electric lighting in the late nineteenth century, especially because it was more complex and more expensive than the existing alternatives of gas or kerosene.... By emphasizing that electric light was scientific, modern and progressive [the early innovators] helped persuade businessmen that it would be appropriate to risk money on the new technology. Thus, the invention of electric lighting was a social process in the sense that inventors and manufacturers had to negotiate with local businessmen regarding the cultural and economic implications of the new technology."[28]

Recognizing the historical pattern of technology turnover offers key insights to create effective strategies to introduce new clean energy technologies. In particular, certain themes emerge from a historical review that are directly relevant to the challenge of today.

First, the transition to a new technology is rarely driven by cost. Most often, the new technologies are more expensive, but they possess new, unique qualities demanded by the marketplace. They typically cannot compete on the basis of price and performance against mainstream, dominant technologies. As noted, Edison's electric light, at the outset, was much more expensive than kerosene or gas, the alternatives for lighting. But it was cleaner, and held a powerful "combination of safety and theatricality" when used for illumination of store fronts and signs, key selling points at the time.[29]

Second, innovative technologies rarely find success by entering directly into mainstream markets. Early success usually occurs in niche markets where the fundamental characteristics of the application are "suited to the merits" of the technology, corresponding with the true *Oxford English Dictionary* definition of "niche."[30] In these applications, the new technologies offer a real, economic value. Typically, the very attributes that lead to failure in mass markets lead to success in these niche markets. Further, because the market size is small, the mainstream incumbents most often do not perceive the new technology as a competitive threat.

Niche markets, then, serve as an incubator to refine and develop the technology, and act as a launch pad into mainstream markets. In this sense, "widespread adoption accelerates the incremental improvements from learning by both users and producers, further speeding adoption and diffusion."[31] From these early applications, innovators are able to improve and tailor the technology to meet the demands of the market, and then advance into the mainstream marketplace. Their subsequent success in disrupting the status quo of established markets has more to do with meeting new demands in the marketplace than in undercutting a competitor on price alone.[32]

Third, people do not switch to new technologies because the existing resource base is growing scarce. This is particularly true for energy transitions. As the saying goes, "The stone age did not end because we ran out of stones." In each major energy replacement of recent history —from wood to coal, coal to oil, oil to gas —the emerging fuel offered values and real economic advantages to consumers that the previous fuel could not deliver. This is important because, as previously indicated, climate change impacts demand that we switch from fossil fuels long before these resources prove scarce.[33]

A fourth theme, evident in Edison's day as well as our own, is that new technologies face fierce responses from incumbent players. They wield powerful political influence to affect the regulatory

Building-integrated photovoltaic panels, such as these at the Science Museum of Minnesota, a project funded with a grant from the Xcel Energy Renewable Development Fund, are a promising market niche for the early adoption of solar energy.

environment in which new technologies must compete. The reaction of the players governing the incumbent technologies will greatly influence the diffusion of a new technology.

A fifth theme is that, in response to incumbent players' reactions, creating "networks of innovation" is critical to overcoming their entrenched benefits and maneuvers. Indeed, U.C. Davis professor Andrew Hargadon has written extensively on the effective management of innovation and notes that breakthrough innovations require "building a community of like-minded and wholly committed individuals who see their shared future in the success of the emerging technologies and industries."[34] Those interested in disruptive change need to organize and align their actions to bring about change, and success does not depend exclusively on technical superiority. In this sense, innovation is "as much social as it is technical."[35]

A sixth theme is that these revolutions rarely are spontaneous or instantaneous. At the close of the 19th century, nearly two decades after the installation of Edison's first plant, less than 5% of the mechanical drives in factories were electric.[36] In the next twenty years, this figure grew as slightly more than half the factories introduced electricity. Interestingly, electricity was most often introduced as a parallel investment alongside existing energy technologies. As one scholar notes, "This sort of overlaying of one technical system upon a preexisting stratum is not unusual during historical transitions from one technological paradigm to the next."[37]

With few exceptions, the adoption rates of innovative technologies are measured in decades. As with electricity, implementation on a wide scale requires working out the details of using the new technology in the context of many quite varied industrial and commercial settings. In networked systems such as electricity with an elaborate connection of grids and power plants, where decisions and components are highly interconnected, these adoption rates are slowed even more. As one business scholar recently observed, these kinds of interconnected networks make it "tougher for companies to dislodge the status quo than if each participant were to act autonomously."[38]

Arguably, an observer in the early part of the twentieth century stood as far distant from the breakthrough of the first electric generating station as an observer today stands from the early generation of photovoltaics, wind turbines and other clean energy sources. Twenty years or so had passed since the introduction of Edison's innovation. And each might remark on the relatively "slow" progress of the technology—entering the 20th century, a mere 3% of all residences in the United States used electric lighting. Today, in the US, a little more than 3% of our power supply relies on clean energy sources.

But as in Edison's time, the small rate of technology turnover in clean energy today could mask a fundamental transformation. Seemingly small innovative activity often portends a larger undercurrent of change that only becomes evident years later. We may be at the cusp of fundamental shift in the clean energy world, especially if we take advantage of the new public tools to speed the momentum toward that transition.

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PUBLIC SECTOR INVESTMENTS

Capital investment will shape the future, and investment is all about technology choice."

— JAMES GUSTAVE SPETH

For all the similarities, one major and hopeful difference exists—Edison did not have significant public sector support to accelerate his market when he started his venture. That support came decades later when his upstart companies became the new entrenched and powerful players. Public agencies lined up to promote monopoly regulation and other forms of capital accumulation that benefited these new incumbents—the electric companies.

Today, at this early stage of the clean energy market, the public sector has an obvious and huge stake in commercial success. Technological innovation in this area has been strongly stimulated by public investments—largely through research and development funding—justified by the pursuit of social goods such as energy diversity, climactic stability, environmental protection, global security and power reliability. But these public good benefits will not be realized if the developed technologies are never adopted in mainstream markets.

The failure of new technologies to reach the market is often attributed to private investors who are unwilling to assume the risks of supporting a new technology, even one with significant public R&D support. This is a key problem in the clean energy area.

There is, perhaps, a simple and direct explanation for this caution by private investors, which is that there are often significant gaps between what a newly developed technology offers and what investors seek. In short, the public and private sectors have different goals. Public investors emphasize performance characteristics and public benefits of new technologies. Private investors, in contrast, are typically more concerned with issues related to the size of the market, quality of the management team,

Public Fuel Cell Alliance

The Public Fuel Cell Alliance (PFCA), a nonprofit project of the Clean Energy States Alliance, was created to assist agencies at state, federal and international levels with new programs to support fuel cells and hydrogen infrastructure activities. While the diversity is impressive, the explosive growth of these programs comes at a cost. There is little coordination or cooperation between these diverse programs. The PFCA is designed to bring these programs together and accelerate the widespread adoption of fuel cell and hydrogen technologies.

PFCA activities are focused on three complementary areas:

- Sharing Information,
- Leveraging federal and state funding, and
- Developing short and long-term strategies for program development.

The PFCA will organize and host meetings to focus discussion on developing short and long-term strategies, including extensive collaboration with private industry partners. For more information, please visit *www.cleanenergystates.org*.

competitive advantages of the technology and liquidity of their investment.

Compounding this mismatch is a pronounced gap between when public sector financing typically stops and when the private sector is willing to invest. After the technology is created, funding for research decreases dramatically. Yet this is also when the funding requirements for a new venture begin. Private investors, however, are more likely to fund a venture with a commercial product and established sales ready for market expansion. While the public funding may have addressed various technological risks, there remain numerous market, information and management risks in this gap.[39]

Clean Energy Development Fund

At a meeting sponsored by the Rockefeller Brothers Fund, Oak Foundation and the Surdna Foundation in November 2003, several European and US parties met to discuss how to expand investment in clean energy technologies. One proposal currently being investigated is creation of a Trans-Atlantic Clean Energy Development Fund (CEDF) for European and North American investors.

Creation of a financing vehicle like the CEDF would:

- Recognize that public and private investors on both sides of the Atlantic have no single specialized vehicle through which joint or parallel investments in clean energy development technologies can be made
- Allow investors to expand their investment portfolios
- Accelerate technology development and transfer
- Create new and mutually beneficial investment relationships in this globally important industrial sector
- Target investments in three categories:
  1. Beta stage technology demonstration projects
  2. Early growth opportunities for commercial scale expansion
  3. Technology transfer

The public sector has the ability to better address some of these risks through effective partnerships that recognize the most important public sector role is to combine leadership with funding. There are long-standing precedents for public and government support to foster innovation, including grants to develop the telegraph and railroad and purchase orders which drove the infant aircraft industry during World War I. Government investments in research and development following World War II spurred the creation of university and corporate R&D labs. In large part, this support took the form of grants and purchases from the public sector.

The public sector now has an important new challenge to create rich and effective partnerships that target the gaps in the innovation process with specific investments. This is especially true with clean energy technologies in the contemporary marketplace. There are simply not enough public subsidy dollars available to make these technologies cost-competitive in conventional, mainstream applications. Moreover, many investors leading teams in high-risk ventures are more interested in the strategic, not merely financial, resources of their investment partners.

These new partnerships are a new role for public intermediation. Public leadership can be used to demonstrate how public and private capital can be combined in pursuit of social goals that may require longer horizons than conventional private investment. It can help bridge the "credibility gap," helping consumers understand the range of options for their personal energy choices and their community's infrastructure choices. And, public leadership can create strategic investments that reduce the perceived risks and attract more conventional, mainstream financing.

There are many risks that serve to dissuade private sector investors away from emerging technologies. It is often difficult to communicate or understand the true potential of a new technology. Costly and time-consuming prototypes are needed, and there are typically few commercial products at the early stages of a technology's development. Often, the managers of these early ventures are more qualified to address technological, rather than market, challenges.

For clean energy companies, these general risks are compounded by risks specific to energy markets. Because they are generally capital and infrastructure improvements, energy ventures have larger cash needs and the time to exit is often several years longer than typical venture capital investments. Energy is viewed as a commodity, with low margins and high price elasticity. Investors are typically wary of entering markets that are highly dependent on government regulation, such as electricity generation, transmission and distribution. Further, the management teams often focus on energy displacement in the mainstream markets, without regard for market realities such as size, customer benefits, profitability, market entry strategies and competitive reactions of incumbents.

For business innovation, the key is to involve private capital. For clean energy, the public sector has a unique role to play by addressing these funding gaps and market inefficiencies that prevent private capital from entering the market. With an understanding of these specific issues, public sector players can be key early-stage, high-risk strategic investment partners, working with private investors to mitigate the risks and establish key public benefits.

In this early stage, the public sector has an obvious and huge stake in the success of clean energy markets. The many public good benefits of these technologies will only be realized if they are incorporated into the public infrastructure.

This is a somewhat new role for the public sector in clean energy, moving beyond the technology creation phase and serving as an investing intermediary. Through public-private partnerships in the pre-commercial and early commercial stages, this public sector involvement can serve to reduce the investment risks, help industry understand the true risk profile, and identify new trends and opportunities.

Some new public players have begun to fill this gap, opening a significant new chapter in how clean technologies could move into mainstream markets. Perhaps most important, these public players are, in the words of Professor Hargadon of the University of Califronia at Davis, filling the vital role of "social construction"—the process by which communities arrive at shared understandings of what can and cannot be done with an emerging technology that stands at the heart of technological innovation.[40]

CURRENT CLEAN ENERGY INITIATIVES

The Clean Energy States Alliance provides an ideal forum for the renewables states to share experiences and learn from each other. We're gaining momentum, and one day will represent the prevailing energy policy in this country."

— JOHN GEESMAN, COMMISSIONER, CALIFORNIA ENERGY COMMISSION

A new set of public funders has emerged in the last few years with a common goal —to develop market demand, infrastructure and competitiveness for new, clean sources of energy. They invest public funds to catalyze the innovation process, moving wind, solar and fuel cell technologies out of the laboratory and toward commercialization. They pioneer new investment models that follow principles of business strategy to build networks of innovation, target specific capital needs and demonstrate clear leadership in creating financing mechanisms to address those gaps.

Stationary fuel cells are a new source of highly reliable and locally distributed premium power. Public funders are now focusing on the indigenous strengths of each state program, and are working together with a common understanding of the market gaps and opportunities for fuel cell and hydrogen infrastructure market through Public Fuel Cell Alliance.

If anything stands out about these state clean energy programs, it is their connection to local market conditions, industries and opportunities. Their focus is on market-responsive strategies that address some of the key barriers—financial constraints, information gaps, immature market infrastructures—and try to create practical solutions to overcome those barriers.

In the first effort of its kind in the United States, seventeen of these public funds from twelve states banded together in 2002 to promote clean energy projects and companies. The funds agreed to support a new non-profit organization—the Clean Energy States Alliance (CESA)—to help them work together. (See *www.cleanenergystates.org*, and Appendix B.)

CESA's members include the clean energy funds from California, Connecticut, Illinois, Massachusetts, Minnesota, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island and Wisconsin. CESA now advances new, multi-state efforts to promote solar, wind, fuel cells and other clean energy projects and investments.

Collectively, CESA members put over $300 million annually into clean energy markets through grants, rebates, loans and equity investments. In the last five years, these funds have invested and obligated more than $1.5 billion through grants, rebates, loans and equity investments. In the coming decade, they are currently budgeted to invest another $2.5 billion.

Internationally, many public funds are currently in discussions about similar multi-party initiatives. A new venture, The Clean Technology Implementation Network (CTIN) focuses on extending the successful collaborative model of cooperation among US state clean energy funds to the international level through exchange on clean energy technology investment and deployment. This network is intended to chart the way toward an expansion of renewable energy worldwide with a commitment to new innovative clean energy finance mechanisms. (More specific information is available in Appendix C.)

These funds are capitalized in a number of ways. In the United States, these funds have typically been created at the state level with money collected from electricity ratepayers through a system benefits charge (SBC).[41] Most were created during the wave of deregulation that swept through the

Low Carbon Technology Alliance

The Carbon Trust (UK), Clean Energy Group (US) and the Federation of Canadian Municipalities created the Low Carbon Technology Alliance (LCTA) in February 2004. Other organizations are expected to join this innovative new effort.

The LCTA will:

- accelerate low carbon technology deployment by closing the "collaborative gap" among practitioners using public investment programs
- share key information among local and regional governments, public funders, companies and NGOs in Europe, the United States and Canada
- focus on energy production from solar, wind, hydro, biomass, ocean thermal, tidal and wave, fuel cells, and related energy storage and conversion technologies, in addition to energy efficiency applications and green building design
- share knowledge needed to build large, durable and sustainable markets for these new technologies
- take advantage of complementary approaches to delivering change by identifying the best practices of each partner

Pension Funds & Institutional Investors

Recently, there has been increasing interest by state pension funds and other financial institutions to incorporate the future risks of climate change into their investment decisions, due in large part to the Coalition for Environmentally Responsible Economies (CERES).

If institutional investors allocate some of their capital toward direct investments in clean energy and low carbon technologies, the results would be extraordinary.

Based on our work and discussions with experts in the field, we have identified the following critical barriers to action in this area:

- lack of information to make sound investment decisions,
- lack of a coordinated funding vehicle, and
- lack of basic education of fiduciaries to understand the opportunity to align investment with mission.

Our principal conclusion is that we must:

- develop new clean energy information networks,
- create new cooperative structures and funding vehicles, and
- inform pension managers and other investors about opportunities and pitfalls.

The end goal must be an educated fiduciary community, a coordinated investment response to the tremendous climate risks, and new fiduciary approaches that will create new sources of capital allocated to opportunities in this area.

electric industry in the 1990s, spurred by public fears that competition might force out all but the cheapest power sources.

This is a new and attractive approach to the public role in clean energy. The focus is on technology innovation, not only policy. The mechanisms employed are targeted investments, not only regulatory mandates. These funds are leveraging private capital to achieve public purpose goals. They are charged with the task of bringing capital to new industries made possible through technology and favorable energy policies. These initiatives show how states have become the key "laboratories of experimentation" for economically and environmentally sound clean energy programs, pioneering a new role as key early-stage, high-risk investment partners.

The challenge now is to better organize these funding efforts to sustain companies or projects from the early research and development stages through to commercial deployment.

State clean energy funds will invest nearly $2.5 billion in the next decade to build new markets opportunities for clean energy.

CONCLUSION

The only relevant discussions about the future are those where we succeed in shifting the question from whether something will happen to what would we do it if did happen."

– ARIE DE GEUS, FORMER HEAD OF GROUP PLANNING, SHELL INTERNATIONAL [42]

We began by stating that our energy future is not predetermined. In fact, there is one truth that is certain—we will shift away from a carbon-based energy system. What is not predetermined is the path and pace we will follow to lead us away from it. The investments that will be made in the power plants of tomorrow—the machines that will power our homes, factories and offices of 2050—depend on the policy, financial and social decisions we make today.

We now know a great deal about how the interplay of capital, policy and choice will work upon our energy future. The process of technology innovation that has brought us everything from laptops to lipstick will operate to create the energy choices for our children and grandchildren.

Certainly, we cannot control this future fully, but we do know enough to take actions today which will influence where we head tomorrow. The question is whether we will take this knowledge and act in sufficient time to introduce designs into our systems that will lead to sustainable energy options.

Based on the actions of these new public energy funds, there is some hope for a more enlightened approach to take hold. The activities of these new public investors represent a new role for public sector investment. Recognizing the divide between technology creation and commercialization, these clean energy funds are focusing on providing targeted investments and partnerships to bridge these pre-commercial gaps. Their activities are serving to foster an accelerated shift from technology development to market focus.

At the same time, venture firms, pension funds and other private investors have begun to explore ways to expand the pool of public and private capital devoted to clean energy. What can these players—angel investors, high-wealth individuals, investment arms of private foundations, pension and retirement funds, states, venture capital firms and private equity investors—do now to catalyze this change?

The problem is scale and timing. Will these nascent efforts take hold and bring these technologies into mainstream markets, and to do so in time to replace our polluting power systems? The cumulative data of climate change impacts suggest that time is critical—we need to act soon to reverse the damage already in the atmospheric pipeline.

The success of efforts to introduce clean energy depends less on the state of the technology and more on our ability to address the barriers and competition in the marketplace. As one practitioner notes, "the reason renewable energy technolo-

gies do not have deeper market penetration in the United States today is *not* that those technologies failed to meet cost and performance goals; it is primarily because the competition did not sit still."[43]

The barriers can be overcome. The competition can be met. But we cannot sit still. In order to leave a legacy for the next generation worthy of our abilities, we need to generate billions of dollars of new public and private investment in clean energy technologies. We need new vehicles to bring about this scale of investment. But most of all, we need organized efforts. This is a massive organizational challenge, one that our best minds in business, finance and government must address.

Can we shift the question from "whether something will happen to what would we do if it did happen?" If so, we must immediately grapple with some formidable challenges, including:

- **Fragmented and immature markets for clean energy**—making it difficult to mount large efforts to overcome the major barriers that exist. We do not have any systematic market infrastructure and communication between practitioners in this area.
- **Unorganized and opportunistic investing patterns**—leaving numerous gaps in the "innovation chain" that prevent promising technologies from reaching larger markets.
- **Public credibility gaps**—both for the abilities of the technologies and the opportunities for real investment.
- **Unreliable market estimates**—hampering efforts to successfully develop market penetration strategies with honest assessments of niche market potentials and, in some cases, furthering credibility gaps through overreaching, unfulfilled projections.
- **Regulatory uncertainty**—adding risks for investors and preventing long-term planning.
- **The need to act quickly**—pressing climate change impacts demand that we act as soon as possible to avoid future climate impacts and mitigate existing climate effects.

While formidable, these challenges are not unique. Many of them are quite similar to the challenges facing the early pioneers of electricity. By combining careful attention to these lessons from the past with over a century of new business and technology strategy, we can meet these market challenges.

The Clean Energy Group is leading several initiatives designed to address these gaps in the clean energy marketplace. Other organizations—NGOs, state funds, foundations, government agencies—are similarly active. Together, we need to develop co-

Climate Group

The Climate Group is a new London-based non-profit organization working to harvest knowledge gained from the pioneering experience of corporations, governments and financiers across the globe and make that available for others to learn from.

The Climate Group's mission is to help preserve the world's climate systems—to slow down climate change by speeding up reductions in greenhouse gas emissions. To achieve this, The Climate Group is:

- activating new momentum in the worlds of politics, trade and finance
- assembling a growing, global circle of greenhouse gas reducers and supporters
- pooling this group's experience of cost-effective and profitable reduction strategies

Please visit *www.theclimategroup.org*.

investment partnerships that integrate the capabilities and resources of the varied players. Here are some suggestions for joint action:

1. **Develop global networks of clean energy practitioners.**
   Much greater coordination, cooperation and joint activities among clean energy practitioners are needed to accelerate clean energy commercialization. Rigorous networks of practitioners can begin to create the "social process" of clean energy innovation that is needed for global change. Some early efforts have begun to build effective, bottom-up collaborations between United States and international partners, such as the Clean Energy States Alliance, Public Fuel Cell Alliance, Low Carbon Initiative and the Carbon Group. However, more effort must be brought to bear on the task of connecting practitioners, sharing best practices, and building synergistic relationships.

2. **Understand processes of technology innovation for clean energy.**
   Coordination, such as the networks suggested above, will yield only uninformed chaos without a common understanding of our shared purpose. There is a vast wealth of knowledge about technology innovation that has not been applied to clean energy. These networks must integrate a learning loop that brings these principles to the forefront of clean energy activity. We need a more articulate and clear set of innovation technology principles to guide investments that support both short and long term public funding decisions. We can begin to take the mystery out of the commercialization process through effective partnerships with practitioners and academic experts.

3. **Organize federal, state, international and private sector activities to create complementary and synergistic relationships.**
   Currently, various federal, state and private players in the US and elsewhere are operating at different places in the technology innovation process. Each has a unique and valuable role, but there is little communication among the players to develop any complementary strategy for how these roles could work better together to leverage each other's success.

   How can the federal government R&D process be better linked with state level demonstration and pre-commercial project investment, which in turn must respect the later stage private investment needs? How can these roles be better realized at the international level?

   Starting such a systematic innovation conversation is an important first step that could lead to a more comprehensive and effective clean energy innovation strategy. Working in partnership with international players, the Clean Energy Group is reaching out to private investors to better understand the role of public funding to fill investment gaps. Similar, multi-party discussions can serve to improve the performance of each party along the innovation process and guide funding decisions in line with other economic development and climate change goals.

4. **Create new public and private funding streams and investment vehicles.**
   Any successful innovation network will require that more capital be mobilized to accelerate clean energy deployment. In order to bring about the billions of dollars in new capital required to bring

While formidable, these challenges are not unique. Many of them are quite similar to the challenges facing the early pioneers of electricity.

clean energy to scale, new funding sources must be created.

Today, a major challenge is organizational—how to educate and bring together public and private market actors to create new dedicated streams of revenue to finance the next electricity revolution? The current funding mechanisms (the rather fragmented assortment of federal, state and private financial programs) are not efficiently or effectively mobilizing existing capital well enough to accelerate clean energy market activity. We need to reach out to other federal, state and municipal governments as well as private investors (venture firms, university and foundation endowments, public pension funds and other institutional investors) to explore mechanisms to create new funding and capital streams to support the scale of clean energy development required during the coming century.

Today, a major challenge is organizational—how to educate and bring together public and private market actors to create new dedicated streams of revenue to finance the next electricity revolution?

Conclusions

Each one of these recommendations can lead to enormous opportunity, but each will require dedicated support, cooperation and long-term commitment by NGO's, government, private and public investors, and the affected communities. This is a multi-generational challenge. To date, the scale and complexity of the problem has not resulted in a commensurate response.

We need to start now to build these flexible institutional answers to take on these problems. We know how, but so far have not demonstrated the will to do so. The key assumption of this report is that a more thoughtful and widespread engagement on innovation approaches and opportunities is needed to make this innovation process more attractive to new capital. This education process will likely require creation of new funding vehicles to make it easier for private and public capital to be brought together.

We need to do all this with an eye to ever changing circumstances, to incorporate new thinking and to admit failure in early efforts and learn from those mistakes in new approaches. Moreover, this must be a bottom-up process, a partnership of government and private industry mediated by noncommercial players, one responsive to local conditions, knowledgeable about markets and sensible enough to adapt to quickly changing circumstances. We do not need a new government bureaucracy to do this job—we need new enlightened networks, as envisioned by Professor Hargadon and others to bring together the key players with an immediate stake in long-term success.

We have begun some of these initiatives through our work in the Clean Energy States Alliance, and through our alliances with various international actors. Those models hold some promise for clean energy collaboration on a much larger level. But much more time, capital and intellectual activity must be applied.

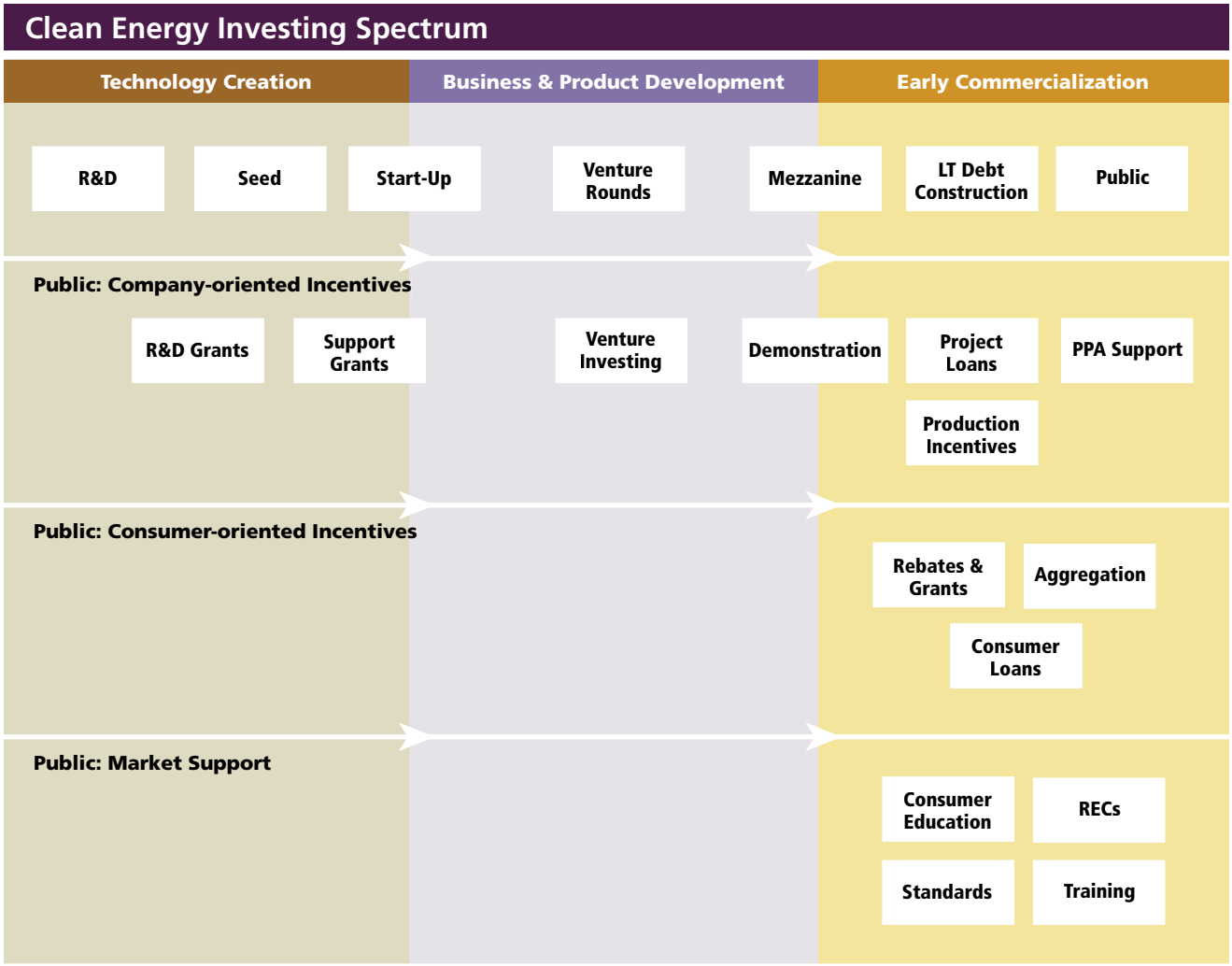
This paper is an open invitation to collaboration, to join with us in this effort. We look forward to working with you.

APPENDIX A

STATE CLEAN ENERGY FUND INVESTMENT ACTIVITIES

It is one of the happy incidents of the federal system that a single courageous State may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments without risk to the rest of the country."

— JUSTICE LOUIS DEMIBTZ BRANDEIS



The activities of the state clean energy funds reach well beyond the traditional technology-creation role. They provide investments that target specific companies and projects, consumer incentives intended to stimulate demand, and general education and market support. Together, these activities are filling the gaps in the critical pre-commercial and early commercialization stages.

Company-oriented activities

Support grants

For companies with proven technologies, support grants can help early ventures prove their technology and conduct initial business planning. For example, Wisconsin Focus on Energy has conducted market assessment analyses for local renewable energy companies. Pennsylvania's Sustainable Development Fund also offers grants for business planning, design, start-up and other costs.

Venture Investing

State clean energy funds have funded a number of start-up companies and provided debt and equity to early-stage clean energy companies. The intention is to find and develop ideas and entrepreneurial teams for companies with proven clean energy technologies. New Jersey's Renewable Energy Economic Development Fund provides recoverable grants to start-up companies. The Connecticut Clean Energy Fund has a broad portfolio of equity investments in clean energy companies. The Massachusetts Renewable Energy Trust made a $2.5 million investment in Evergreen Solar in 2003, among other investments.

Demonstration

Demonstration projects seek to overcome barriers related to education, marketing and visibility through consumer exposure. Projects can also address issues related to limited customer demand by encouraging familiarity, acceptance and demand. The high visibility of most demonstration projects helps foster public support. For example, the Long Island Power Authority's Clean Energy Research, Development and Demonstration program has installed fuel cell demonstrations projects across Long Island.

Project or Company Loans and Financing

Many of the funds provide subordinated debt or other favorable financing (for example, royalty payments) in instances where a company or project may not be readily financed by banks. The subordinated nature of the loans, which provides that other commercial lenders are given priority to be repaid, helps to reduce the risk for mainstream commercial lenders. For example, in Pennsylvania, financing of up to $5 million is available through subordinated debt at favorable rates.

PPA Support

A critical need for project development is securing long-term power purchase agreements (PPA). Funds are actively trying to develop mechanisms to secure these contracts and develop more projects. For example, Massachusetts recently announced a $30 million program to support monetization of the RPS requirements. The program will allow for long-term contract support through agreements to purchase renewable energy credits (RECs), put options on RECs, which serve to provide a price floor, and price collars (put and call options) on RECs.

Production Incentives

To help develop new generation projects, funds are offering direct financial incentives to make sales of power from clean energy projects competitive with mainstream electricity prices. These incentives are usually tied directly to the amount of electricity produced.

Consumer-oriented activities

Rebates and grants

Direct subsidies through grants or rebates can reduce the capital cost of new clean energy installations for residential or commercial customers. In California, for example, photovoltaic and wind energy systems have been installed on over 5,300 homes and businesses, providing over 20 MW of capacity. Many other states have similar programs. The Illinois Clean Energy Community Foundation, for example, offers direct rebates for solar photovoltaics systems and small wind turbines. The Energy Trust of Oregon, similarly, offers an incentive for installation of PV systems.

Aggregation

Aggregating large purchases is another mechanism used to stimulate demand for green power. The Rhode Island Renewable Energy Fund created the Rhode Island Renewable Energy Customer Aggregation program in order to educate large energy users about renewable energy purchasing opportunities, and to show them the direct benefits of clean energy to their businesses, colleges, and universities.

Consumer loans

Favorable financing allows customers to avoid the full up-front cost of new clean energy installations. For example, the Ohio Energy Loan Fund provides an incentive for energy efficiency and renewable energy choices by reducing the interest on standard bank loans for qualifying Ohio residents.

Market support activities

Many of the state fund activities are not directed toward any specific projects, companies or consumer groups, but offer widespread support to the industry.

Consumer Education

Grants and incentives can be used to conduct general education to raise awareness and interest in clean energy. Five states (MA, CT, RI, NJ, PA) have banded together, for example, with a goal to brand clean energy in a way that convinces Americans that increasing clean energy is important, desirable and achievable. They have hired an advertising agency to produce common print, radio and television materials.

Interconnection standards

Establishing consistent, well-understood standards for how clean and distributed energy sources are connected to the electricity grid is critical for market penetration.

Green tags and RPS support

In order to foster great liquidity for clean power, renewable energy credits ("RECs" or "green tags") are often used to track the environmental attributes of the energy supply. State clean energy funds have employed a variety of approaches to support these markets, including financial incentives to companies selling tags, education consumers or improving verification of RECs. For example, the five Pennsylvania funds contributed to a joint education effort to increase purchases of green power through RECs.

Training and Certification

In order to develop the supporting industry infrastructure, some states are supporting the training and development of clean energy professionals. For example, NYSERDA is partnering with renewable experts to design technical training, outreach, and market support initiatives for renewable energy technologies and green power markets as part of the "Power Naturally" program.

APPENDIX B

CLEAN ENERGY STATES ALLIANCE MEMBERS

This new multi-state coalition is already moving fast to advance innovative clean energy solutions that create new jobs and lead to increased energy security for America. These dynamic partnerships support cutting edge renewable energy companies, foster shared learning among states and carry the message that clean energy can deliver substantial economic and environmental benefits right now."

– ROB PRATT, DIRECTOR, MASSACHUSETTS TECHNOLOGY COLLABORATIVE RENEWABLE ENERGY TRUST

California Energy Commission —Renewable Resource Trust Fund

Beginning in 1998, The Renewable Resource Trust Fund is funded by a systems benefit charge collected from the state's three largest investor-owned utilities. The program is administered by the California Energy Commission, and $135 million is collected annually to support existing and new renewable energy facilities through financial incentives, emerging renewables through consumer capital buydowns, and consumer education programs.

California Energy Commission —Public Interest Energy Research Fund

The Public Interest Energy Research Fund was created in 1998 to fund public interest research and development, which had been previously administered by the investor owned utilities prior to deregulation. The Energy Commission administers the program with $62.5 million that is collected annually from the state's three largest investor-owned utilities.

Connecticut Clean Energy Fund

The Connecticut Clean Energy Fund, created in 2000, is administered by Connecticut Innovations, a quasi-government agency. Approximately $20 million was collected through a system benefit charge in 2003. The funds are used to foster the production and use of energy through debt and equity investments in enterprises and initiatives, consumer education and ratepayer incentives.

Energy Trust of Oregon

The Energy Trust of Oregon (ETO) is a nonprofit organization formed to invest in energy efficiency and renewable energy. ETO receives about $50 million per year from funds collected through system benefit charges from the state's largest investor-owned electric utilities and a natural gas utility. About 75% of the ETO's investments are for cost-effective conservation. Funding for renewable energy projects averages $10 million per year, or about 20% of the annual funds.

Illinois Clean Energy Community Foundation

The Illinois Clean Energy Community Foundation was created in 1999 to improve energy efficiency, advance the development of renewable energy resources and protect natural areas and wildlife habitats throughout Illinois. Funds are distributed through grants to 501(c)(3) nonprofit organizations and local or state government entities. Illinois Clean Energy's grant programs are supported by a $225 million endowment provided by Commonwealth Edison.

Long Island Power Authority—Clean Energy Initiative

The Long Island Power Authority's Clean Energy Initiative (LIPA) was created in 1999 following LIPA's 1998 takeover of the transmission and distribution system on Long Island. LIPA's CEI consists of a mix of energy efficiency programs and the fostering of clean and/or renewable generation technologies on Long Island.

Massachusetts Renewable Energy Trust

The Massachusetts Renewable Energy Trust Fund was created by legislative restructuring of the electricity market in 1997. The Trust is administered by the Massachusetts Technology Collaborative (MTC) and funded through a system benefits charge. In 2003, Trust revenues were approximately $39 million. The Trust has established an equity investing fund, numerous customer incentives and public education campaigns, as well as demonstration projects.

Pennsylvania Funds

- **Metropolitan Edison Company Sustainable Energy Fund**
- **Pennsylvania Electric Company Sustainable Energy Fund**
- **Sustainable Development Fund**
- **Sustainable Energy Fund of Central Eastern Pennsylvania**
- **West Penn Power Sustainable Energy Fund**

Pennsylvania has five clean energy funds. In the late 1990s, agreements related to restructuring and utility mergers created the funds, which are now managed by nonprofit development financial institutions and community foundations. The funds operate under an enterprise model that provides loans, investments and grants to companies and projects in Pennsylvania that promote renewable energy, clean energy technologies and energy efficiency.

New Jersey Clean Energy Program

The New Jersey Clean Energy Program provides education, information and financial incentives for renewable energy and clean energy systems. The New Jersey Board of Public Utilities (BPU) administers and implements all of the renewable energy programs which include a rebate program, a low interest finance program for large-scale renewable energy systems and a renewable energy business development program.

New York State Energy Research & Development Authority

NYSERDA administers the New York Energy Smart program to support public benefit programs, including renewable energy, during the state's transition to a competitive electric market. NYSERDA uses targeted solicitations to distribute funds, mainly as competitive grants with performance incentives.

Ohio Energy Loan Fund

The Ohio Energy Loan Fund provides an incentive for energy efficiency and renewable energy choices by reducing the interest on standard bank loans for qualifying Ohio residents. The Fund was established by the Ohio General Assembly under the 1999 electric restructuring act (Senate Bill 3). The Fund is administered by the Office of Energy Efficiency within the Ohio Department of Development.

Rhode Island Renewable Energy Fund

Rhode Island created the nation's first clean energy public benefit fund when the state passed its restructuring legislation in 1996. The Renewable Energy Fund that resulted was initially administered by a utility-based collaborative. The Rhode Island State Energy Office took over the administration of the fund in January 2003.

Wisconsin Focus On Energy

Wisconsin Focus on Energy provides public awareness activities, education & training, facilitation and project financing for renewable energy. Focus on Energy is administered by the Wisconsin Renewable Energy Network (WREN), a consortium of Wisconsin-based renewable energy organizations and businesses led by the Wisconsin Energy Conservation Corporation (WECC). WREN started the statewide program in March of 2001 after a three year pilot in Northeast Wisconsin.

Xcel Energy Renewable Development Fund (MN)

The Xcel Energy Renewable Development Fund (RDF) was created in 1994 by state legislation. Xcel Energy currently pays $16 million annually into the fund. Project funding is in the form of grants and the program supports both commercial technologies and research and development. The Fund is administered by Xcel Energy, with a five member Board responsible for the oversight of the Fund.

APPENDIX C

INTERNATIONAL EFFORTS

We hope that by bringing together a wide range of international practitioners who are on the leading edge of practical low carbon deployment programs, knowledge sharing needed to build large, durable and sustainable markets for these new technologies can increase rapidly."

— PETER MALLABURN, DIRECTOR, GOVERNMENTAL AND EXTERNAL AFFAIRS, THE CARBON TRUST (UK)

There are several international public or quasi-public funds that serve as counterpart investment mechanisms to the US state clean energy funds. These funds, and others, are currently discussing possible collaborative arrangements to better organize and expand their efforts.[44]

The Carbon Trust

The Carbon Trust is an independent not-for-profit company funded in part by the UK Government and in part by the UK Climate Change Levy. Its mission is to help the UK move to a low carbon economy by enabling business and the public sector to reduce carbon emissions and capture the commercial opportunities of low carbon technologies. It directly supports the UK's goal to reduce carbon emissions by 60% and create a low carbon economy by 2050 through energy efficiency, carbon management and investment in low carbon technologies. Since its inception in 2001, the Carbon Trust has committed £29.9 million to the discovery and development of low carbon technologies and businesses by working with various stakeholders (academic, early-stage, pre-commercial, corporate research and investors) to identify innovative technologies, test concepts, provide viability and define future markets.

Clean Energy and Infrastructure Development Bank

The primary objective of the Clean Energy and Infrastructure Development Bank (CEIDB) is to finance small hydropower as well as other renewable energy projects and clean energy infrastructure projects by mobilizing savings within Nepal. The CEIDB aims to generate competitive returns for its shareholders by financing environmentally responsible, financially sustainable clean energy projects. It will mobilize long-term capital for private sector clean industry and infrastructure projects, contribute to Nepal's social and development goals and help reduce global warming. The CEIDB brings together a unique combination of local individual and institutional investors, foreign institutional investors and the general public.

Fideme

Fideme is a public-private investment fund based in France for renewable energy and environment projects. In 2003, the total value of the fund was 45 million euro. Fideme is dedicated to providing intermediary financing between equity and debt, and to financing projects based on proven technologies and improving the environment. Fideme does not provide equity, nor does it finance projects with non-proven technology or provide subsidies through grants.

Green Municipal Enabling Fund

The Green Municipal Enabling Fund (GMEF) operates on a national basis in Canada through a partnership between the Canadian federal government and the Federation of Canadian Municipalities. The GMEF provides support to Canadian municipalities and their public- or private-sector partners for feasibility studies of new renewable energy projects. Created through a $50 million (CAD) endowment from the Canadian federal government, the GMEF was launched in 2000 and is planned to operate until 2007.

Eligible renewable energy projects include:

- on-site energy generation and co-generation technologies;
- landfill gas capture to generate electricity and/or heat or produce liquid fuels;
- installation of renewable energy technologies/building elements (i.e., solar walls, solar thermal heating); and,
- micro-hydro, wind, solar thermal, solar photovoltaic or biomass projects used to meet community energy needs

Other project types are also eligible for funding through the GMEF, including those with the potential to improve environmental performance in the following areas: energy, water, solid waste management, sustainable transportation services and technologies, and sustainable community planning.

Green Municipal Investment Fund

A sister fund to the GMEF, the Green Municipal Investment Fund (GMIF) offers interest-bearing loans, loan guarantees, and grants toward the implementation of a similar range of municipal environmental projects, including projects involving renewable energy technologies in Canada. The $200 million (CAD) GMIF, also managed through a partnership between the federal government and the Federation of Canadian Municipalities, is designed to operate in perpetuity as a revolving fund. Through the GMIF, eligible projects may apply for loans covering up to 15% of project costs (25% in exceptional cases), at an interest rate 1.5% below the Bank of Canada bond rate with payback periods of four to ten years. Supported renewable energy projects cover a wide range of technologies (i.e., wind, solar, geothermal, biomass, landfill gas) and applications (i.e., solar water heating, large-scale grid-connected wind farm) to those supported by the GMEF.

Sustainable Development Technology Canada

Sustainable Development Technology Canada (SDTC) has a $350 million (CAD) endowment and provides incentives to partnerships seeking to develop or demonstrate new technologies that address climate change and clean air issues. Eligible technologies include energy exploration, production, transmission, distribution, and utilization, as well as waste management, transportation, emissions controls, and enabling technologies (i.e., communication software, controls). Renewable energy and hydrogen technologies are eligible within each stage where applicable. SDTC provides gap financing and seed financing to seed the development of new technologies.

Toronto Atmospheric Fund

The Toronto Atmospheric Fund (TAF), established by the Toronto City Council in 1991, offers support for projects with the potential to mitigate global climate change and improve Toronto's air quality. City of Toronto agencies and departments, non-profit organizations, registered charities, and public institutions and schools are eligible to apply for grants and loans in the areas of renewable energy, energy conservation and efficiency, and reduced fossil fuel content of energy sources. Individuals, for-profit organizations, and applicants from outside Toronto are not eligible.

ENDNOTES

1 Vaclav Smil, *Energy at the Crossroads*, (Cambridge: MIT Press, 2003), 125.

2 Smil, 35.

3 Smil, 124.

4 Andrew Hargadon and Yellowlees Douglas, "When Innovations Meet Institutions: Edison and the Design of the Electric Light," Administrative Science Quarterly 46 (2001): 484.

5 Hargadon and Douglas, 481.

6 Paul A. David, "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox", The American Economic Review 80, no. 2 (1990): 355.

7 Smil, 38.

8 Goldfarb, Brent. "Adoption of General Purpose Technologies: Understanding Adoption Patterns in the Electrification of US Manufacturing 1880-1930" (Nov. 2001)

9 Phil Angelides. "A New Era Of Environmental Investment And Responsibility" Remarks by California State Treasurer Phil Angelides to the Institutional Investor Summit on Climate Risk, UN Headquarters, New York City (November 21, 2003).

10 *World Energy Investment Outlook (2003) – 2003 Insights*, (Paris: International Energy Agency, 2003), Executive Summary, 1.

11 For our purposes here, "clean energy" encompasses a suite of electricity generating technologies that include photovoltaics, wind turbines, geothermal, biomass generation, and fuel cells. Each of these energy sources result in reduced emissions, environmental impact and a movement away from fossil fuels and nuclear power. Clean energy technologies can also encompass solar thermal, energy efficiency, green building and smart growth strategies. However, we limit this discussion to electric generation. Fuel cells have a vital role to play in the creation of a low-carbon energy system, allowing for storage and transport of energy through renewably-generated hydrogen. Each of these technologies can be deployed in regimes of central generation, but each also has attributes that suit it to distributed applications.

12 Joel Makower, Ron Pernick and Clint Wilder, "Clean Energy Trends," (Oakland: Clean Edge, 2004), 2.

13 "Beyond Carbon", *Economist*, February 10, 2004.

14 Jesse Ausubel, "Does Energy Policy Matter?" (presentation to Keystone Conference, February 20, 2004).

15 Jeremy Leggett, "The low carbon imperative for solar energy: in search of environmentally-constrained targets and timetables for global solarization," Paper for the Solar Circle, 2003.

16 Joe Chaisson and Michael Stoddard, "Protecting Our Biosphere: A Comprehensive Guide to Climate Change" (Rockport, Maine: Environment Northeast, 2002), 4.

17 Many of these findings can be found in an earlier report released by Clean Energy Group, *Clean Energy Initiative: How Foundations, State Funds and Social Investors Could Pursue Joint Investments*, available for download at www.cleanenergystates.org/library/Reports/CEI_Final_July03.pdf.

18 According to a June 2003 multi-client study by Navigant Consulting, the worldwide renewable energy equipment business is projected to grow from $17 billion per year in 2002 to an estimated $35 billion per year by 2013. The study also concludes that, "By 2013, Most renewable energy options are expected to be competitive with grid power in the U.S. – without incentives." Lisa Frantzis, "The Changing Face of Renewable Energy," Navigant Consulting (June 18, 2003) (50 page public study) (*www.navigantconsulting.com*) and "Impact of Renewable Energy and Market Changes on the Electric Industry," Lisa Frantzis, PowerGen Renewable Energy Conference, Las Vegas, March 3, 2004. This same study forecasts a 9.2% compounded annual growth rate for renewables globally, compared with 2.4% annual for conventional electric generation from 2003 – 2013. (Elisa Wood, "How to Sustain the Green Energy Boom in the US", *Renewable Energy World*, Nov-Dec 2003.)

19 Nth Power, press release, March 3, 2004.

20 "Building the Energy Internet", *Economist*, March 11, 2004.

21 This report focuses on the need to create more public and private capital in this market segment, and how various partnerships and networks can accelerate positive change. Of course, the success of that effort will depend on part on the role of public policy—various regulatory mandates such as the Kyoto protocol and state requirements such as the Renewable Portfolio Standard. Investment decisions can be heavily influenced by these policies. On the other hand, such policies do not inevitably move investment. Private investors often are skeptical about the long term sustainability of regulatory created markets. In such cases, there are enormous barriers to mobilize capital even in the most beneficial policy environments. The recommendations we make here assume positive policy outcomes, but recognize the hard work that must be done regardless of the policy environment in which investors operate.

22 Clayton M. Christensen, *The Innovator's Dilemma*, (Boston: Harvard Business School Press, 1997), xix.

23 Hargadon and Douglas, 477.

24 Walt Patterson, *Transforming Electricity* (London: Earthscan, 1999), 47.

25 L.J. Davis, *Fleet Fire: Thomas Edison and the Pioneers of the Electric Revolution*, (New York: Arcade Publishing, 2003), 203.

26 "Innovator's Insights #8", Clayton Christensen, March 22, 2004

27 Bernard Carlson, *Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, 1870-1900*, (New York: Cambridge University Press, 1991), 206.

28 Carlson, 355.

29 David E. Nye, *American Technological Sublime*, (Cambridge: MIT Press, 1999), 146.

30 "Niche" is often interpreted, mistakenly, to be synonymous with "small." In fact, the appropriate definition from the *Oxford English Dictionary* is "A place or position adapted to the character or capabilities, or suited to the merits, of a person or thing." (*Compact Edition of the Oxford English Dictionary*, Oxford University Press, 1971.) We underscore this clarification here because these niche markets, while often overlooked or dismissed by incumbents because of their current size, are rarely limited in their potential to grow into large and, ultimately, disruptive markets.

31 John A. Alic, David C. Mowery, and Edward S. Rubin, "U.S. Technology and Innovation Policies: Lessons for Climate Change," (Arlington: Pew Center on Global Climate Change, 2003), iv.

32 These "niche" markets are likely more relevant for "disruptive" distributed generation technologies, delivering new values to end-use customers. This could include power reliability from fuel cells avoiding the risks of power interruption, or solar power for developing country markets that have never been served by the grid, thus addressing new, currently "non-consuming" markets. Certainly, there are many healthy debates to be engaged about which technologies are "disruptive" or "sustaining", and caution must be taken not to oversimplify the assorted challenges of each clean energy technology. Still, these theories can yield useful insights when applied to each. For example, centrally generated wind energy may be a "sustaining" technology for producing commodity electricity, but a "disruptive" technology if used to produce hydrogen.

33 Of course, this is not to say that scarcity never influences technology turnover or switching behavior. If the price of oil increases to $100 a barrel due to real or perceived threats to continued supply from the Middle East or other areas, that economic signal would surely influence investment in alternatives and customer behavior. For more details, see Stephen Leeb and Donna Leeb, *The Oil Factor* (New York: Warner Business Books, 2004).

34 Andrew Hargadon. *How Breakthroughs Happens: The Surprising Truth About How Companies Innovate*, (Boston: Harvard Business School Press, 2003), 119.

35 Hargadon, ix.

36 David, 355.

37 David, 356.

38 Bhaskar Chakravorti, "The New Rules for Bringing Innovations to Market," *Harvard Business Review*, March 2004. p. 60.

39 This is sometimes referred to as the "Valley of Death." For a more detailed examination of the funding dilemma, see "Bridging the Valley of Death: Transitioning from Public to Private Sector Financing" by L. M. Murphy and P.L. Edwards (National Renewable Energy Laboratory, NREL/MP-720-34036, March 2003)

40 Hargadon, Andrew, personal communication.

41 There is a wide range of funding streams and management oversight among the various funds. Other funds received their money in lump sums either as a result of a settlement of a utility merger or sale of generation assets. In some cases, government agencies manage the fund activities, while in other cases the funds are managed by non-governmental non-profits agencies.

42 Bernd Kasemir, et. al., ed., *Public Participation in Sustainability Science*: *A Handbook*, (Cambridge: Cambridge University Press, 2003), 201.

43 Joe Romm, *The Hype About Hydrogen: Fact and Fiction in the Race to Save the Climate,* (Washington: Island Press, 2004), 60.

44 We profile here selected public funds that have a specific clean energy mandate and serve as funding agencies. We do not cover the emerging crop of carbon funds related to the Kyoto Protocol or survey individual EU member financial support mechanisms (i.e., feed in tariffs and traditional renewable energy subsidies).

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Clean Energy Group (CEG) is a nonprofit organization established in January 1998 to increase the use of cleaner energy technologies in the US and abroad through creative financing, business partnerships, public policy and advocacy. CEG manages the Clean Energy States Alliance (CESA), a new nonprofit organization of state clean energy funds working on multi-state strategies. CEG also manages the Public Fuel Cell Alliance (PFCA), a new consortium of public fuel cell funders collaborating on fuel cell and hydrogen infrastructure technologies.

For More information:
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Reshaping an industry requires a deep understanding of the forces that act upon the key players—forces that powerfully influence what they choose and cannot choose to do. In my research, I've looked at how the innovation process can be more predictable, enabling growth builders to use disruptive strategies to increase their probability of success. The theories behind my work have not only been applicable to individual companies, but industries as well. In the energy industry, for example, efforts are underway to disrupt the system with clean energy technologies.

This report, written by the Clean Energy Group, looks at the energy industry from a disruptive point of view. If the natural process of disruption is allowed to proceed, it would bring about change that would produce critical social, economic, and environmental benefits. By looking at the industry through the lenses of my research, I hope this report helps you frame the key issues in a unique and powerful way.

CLAYTON CHRISTENSEN
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