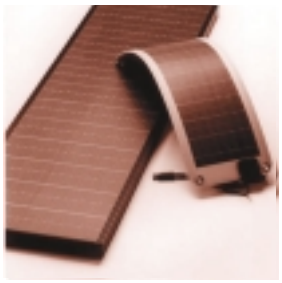
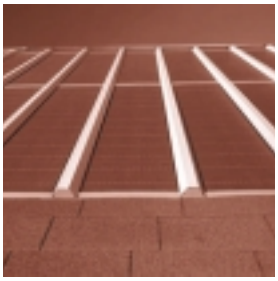
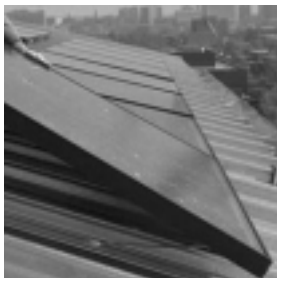


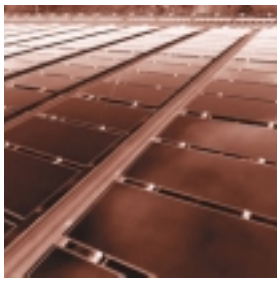


SOLAR OPPORTUNITY ASSESSMENT REPORT

Presented by the
Solar Catalyst Group

DECEMBER 2003





SOLAR CATALYST GROUP

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EXECUTIVE SUMMARY

What will it take to transform solar energy from a niche resource into a competitive, mainstream technology – and beyond, to serve society with solar's full promise? This Solar Opportunities Assessment Report, or SOAR, attempts to answer that simple but complex question and offer some possible pathways forward. It examines what is needed to grow the U.S. solar industry — incrementally into a thriving industry, as well as through bold, audacious measures that could dramatically accelerate the transition to a clean-energy future. It focuses on three pathways for solar's future over the next quarter-century: Current Growth, Accelerated Growth, and Hypergrowth, and describes the challenges and opportunities within each.

SOAR is based on in-depth interviews with more than 30 leading authorities in the solar field to understand their perceptions and best thinking about the state of the solar industry, the challenges the industry faces, and where the best opportunities lie to break through those barriers to accelerate the growth of solar photovoltaics (PV). The interviews were complemented with additional research on and knowledge of the solar industry as well as with work done for our 2002 report *Bringing Solar to Scale*, which promoted a plan to dramatically ramp up the supply and demand for solar photovoltaics in a way that created a cost-competitive global industry in the state of California. This research was conducted by Clean Edge, Inc., on behalf of the Solar Catalyst Group.

Among the key challenges to growing the U.S. solar marketplace are:

- its small production scale, which keeps quantities low and prices high;
- on-again-off-again government funding of solar research and development;
- a dearth of financing solutions, pricing solar out of reach of most users;
- a patchwork of regulations related to solar, forcing manufacturers and buyers of solar systems to meet different requirements in each state;
- a lack of coordination among companies, government agencies, the solar and building industries, or potential buyers of solar systems;
- a lack of standardized, plug-and-play systems that would greatly reduce the complexity and cost of designing and installing a solar-energy system; and
- a lack of education about solar's benefits to a variety of audiences.

THREE KEY LEVERS

SOAR centers on the three key levers of the solar industry: technology, policy, and finance.

Technology challenges include the need for breakthrough improvements, not just incremental ones, that can dramatically reduce solar's costs and improve its efficiency and reliability. This is due in part to inadequate government support for research and development, as well as investors' sense that the potential market for solar is too small to justify massive infusions of capital.

But there is a wealth of untapped opportunities that could significantly improve solar's appeal. These opportunities include improving economies of scale by building larger plants; improving the "balance of system" components of a solar installation, such as inverters; and better integrating components so that solar systems can be more cost-effective to build, install, and operate. Other potential breakthroughs are budding solar manufacturing technologies that could lower prices, as well as building-integrated systems, such as solar shingles, that could greatly reduce installation costs.

Despite growing investments by some of the larger players, decreased government funding and relatively meager venture capital investments in the earliest-stage solar start-ups undercut the chances that the market will see a technological breakthrough in the near term. Like other technologies that have overcome development hurdles and been widely adopted, PV technology will continue to improve and steadily drop in cost, but it will be an incremental evolution. As it has with other technologies, a major government-sponsored R&D push could greatly accelerate the process.

Policy challenges center on the lack of government support for solar, relative to conventional energy technologies. Like coal, oil, and natural gas, solar is dependent on supportive policies and initiatives at the local, state, and federal levels. Few solar markets in the world today are cost-competitive without government support, except for niche markets such as off-grid power for rural electrification, water pumping, and emergency signs and phones.

Among the key challenges and barriers are a lack of federal policy and regulations; few, if any, large, long-term government incentives and commitments; a patchwork quilt of state-level programs threatened by state budget woes; subsidy programs that artificially inflate prices; and resistance from utilities and other incumbent players.

Despite such challenges, there are several policies and programs that could help move solar from miniscule to mainstream. They include subsidies that decrease over time as solar markets grow, thereby reducing the chances that subsidies can artificially inflate solar prices; national standards for net metering and interconnection, which are critical in guaranteeing a level playing field for solar power in utility markets; time-of-use pricing, which reflects the cost of energy when it is most scarce and in highest

demand — during peak hours, when solar energy systems are most productive; renewable portfolio standards at both state and national levels, especially ones that "carve out" a specific portion for solar; and large, long-term purchases of solar systems by government agencies.

Finance presents additional challenges and opportunities for solar. Cost and affordability are the key detriments for many would-be solar buyers, whether consumers, businesses, or governments. In many cases this is due to a lack of understanding of solar's costs and benefits. Easy financing remains a weak link as purchasers face a dearth of compelling and affordable financing opportunities. And there is a need for financiers to reassess the risks of solar, giving large-scale solar projects better financing terms from lending institutions.

Among the opportunities in the finance arena are loan or mortgage-related instruments that make financing of solar easier for residential and small-business customers; new financing instruments; and new market players. Other means to ease financing challenges could include low interest rates, akin to those used successfully by automobile dealers; utility incentives, including the ability for customers to finance solar purchases through their monthly bills; government procurement initiatives that account for total life-cycle energy costs; simpler, faster rebates; tax credits; and solar service companies, through which customers buy solar energy without necessarily investing in solar hardware.

THREE KEY STRATEGIES

Along with these three levers, we identified three cross-cutting strategies that need to be addressed to help bring solar to scale:

Education. One common frustration is the lack of reliable, comprehensive, and easily accessible information resources about solar — its costs, benefits, and when and how it makes sense. Critical information gaps can be found in all corners of the market, from manufacturers and installers to end users of all stripes and to policy makers.

Standardization. The lack of plug-and-play solar systems, whether for residential or commercial/industrial buyers, frustrates buyers and sellers alike. For the former, buying solar requires a dizzying array of options and technical decisions; for the latter, each new installation requires resource-intensive one-off design and installation plans.

Market Development and Aggregation. Leveraging the power of bulk purchases from government agencies, companies, homeowners, and others, thereby lowering prices through economies of scale, is a compelling means of bringing solar to scale. There is a wide range of possible aggregation strategies, each with its own challenges and opportunities.

Levers and Strategies

Following are examples of how the three key strategies interact with the three key levers.

	EDUCATION	STANDARDIZATION	MARKET DEVELOPMENT AND AGGREGATION
TECHNOLOGY	■ Information on developments and emerging technologies ■ Enhanced awareness of solar benefits ■ Easy-to-use tools to rate solar PV cost projections by region and application ■ Training installers and maintenance personal	■ Improved balance of system components ■ Improved systems integration ■ Simpler, plug-and-play systems ■ Integration of solar into new buildings ■ Standardization of marketing claims of system power output and warranties	■ Improved economies of scale ■ Advances in technology and manufacturing ■ Private-sector bulk purchasing and buyers' clubs ■ Bulk purchases from home builders, universities, others
POLICY	■ Educating regulators and politicians about economic and environmental potential of solar ■ Working with trade groups to develop policies promoting solar ■ Educating policy makers on best practices and what's worked elsewhere	■ National net metering and interconnect laws ■ Time of Use rates ■ Smart meters/invest in grid to make it energy web ■ Feed in laws ■ Building codes for incorporating solar	■ Large, long-term government purchase orders ■ Federal and state renewable portfolio standards with solar carve outs ■ Buy-down programs with declining subsidies ■ Government purchase guarantees
FINANCE	■ Information about the true costs of energy (including the high costs of subsidies for conventional industries) ■ Dissemination of best practices in financing ■ Enhanced consumer awareness of buy-downs and utility programs	■ Simpler financing mechanisms and loan applications ■ Ability to include solar purchases in mortgages ■ Solar Bank/SUN ■ Wide availability of low solar interest rates ■ Marrying efficiency with solar	■ Solar-friendly tax credits and policies ■ Solar futures market ■ Secondary markets ■ Solar utilities/ESPs delivery solar kWh not solar systems

Each of these strategies can be combined with the three levers to create a menu of options and opportunities for spurring solar's growth. For example, at the confluence of "Technology" and "Standardization" is the need to improve balance-of-system components to create simpler-to-install, "plug and play" solar systems; and the standardization of marketing claims about solar, such as system power output and warranties. At the confluence of "Finance" and "Education" is the need for information about the true costs of energy, including the high cost of subsidies for conventional energy technologies; the dissemination of best practices in financing; and enhanced consumer awareness of buy-down and utility solar programs.

A VISION FOR THE FUTURE

All of the strategies and ideas above can help accelerate solar beyond its current growth path. But what about an even grander vision — a highly ambitious effort based around an audacious, man-on-the-moon-by-the-end-of-the-decade type of goal? A goal that would transform the way industry, politicians, and the public think about solar, and in which a myriad parties and interest collaborate to create a robust solar future. One that would ensure that solar represents a substantial portion of the

energy needs for America and the world. In other words, a “Manhattan Project” for solar.

Clearly, there are potentially as many big visions as there are solar experts. We propose one potential vision, which we've dubbed the SHINE — Solar High-Impact National Energy — Project. The SHINE Project calls for 290 gigawatts of cumulative installed PV in the U.S. by 2025, providing 10% of total U.S. electricity consumption.

SHINE involves two concurrent pathways, one promoting products — the accelerated manufacture, purchase, and installation of solar equipment — and the other promoting services — a new generation of solar energy utilities.

Products: Massive Industry Ramp-Up. To rapidly bring solar to scale requires a simultaneous, coordinated ramping up of both supply and demand. This overcomes the chicken-and-egg problem of high prices depressing demand, which keeps prices high. And a short-term or one-time increase in demand won’t work. For manufacturers to scale up their operations or build new plants requires what strategic planners industry analysts refer to as “sustained, orderly growth” — steadily rising orders over a period of several years.

Among the components needed for the ramp-up are large corporate and institutional purchases, including from the U.S. federal government and the military, to ensure a sustained, orderly market for solar manufacturers; national incentive programs, modeled after the buy-down programs of California and other states; manufacturer incentives, to lure more large companies to set up solar-manufacturing plants on U.S. soil; attracting new and well-funded players into the market; utility cooperation; and changes in local building codes. There would also be the need for workforce training, to ensure a solar-savvy job force, and ample quantities of public education to help business and residential customers fully understand and exploit solar opportunities available to them.

Services: Distributed Solar Utilities. In addition to deploying thousands of megawatts of solar equipment, as described above, there is a need to create new solar service companies that can offer customers the benefits of solar without the upfront expense. The second part of the SHINE Project calls for creating solar utilities or service companies in which customers — residential, commercial, industrial, and government — receive solar-generated power from nearby panels, perhaps on their own roofs, that are owned by third parties: in effect, solar utilities.

Such a system offers a variety of benefits to both buyer and seller. The system owners (the solar utilities) handle all aspects of installation, operation, financing, and maintenance, and own the systems, even when installed on a customer’s roof; the solar utilities receive long-term purchase commitments for electricity from the building’s occupants while their customers receive guaranteed fixed prices. The solar utility can

occupants while their customers receive guaranteed fixed prices. The solar utility can sell any excess energy back into the grid at market prices, and also receive all rebates, incentives, depreciation, and tax benefits.

It is important to note that such solar services should not be limited to rooftops. There are vast untapped "fields" of solar energy to be harvested on parking lots, brownfields, covered reservoirs, and other large, open spaces. Moreover, there may be significant opportunities to deploy solar energy in manufacturing hydrogen for the emerging fleet of fuel cell-powered vehicles, thereby creating another major market niche for solar panels and services.

SHINE would require other components, among them a national Renewable Portfolio Standard, mandating that a certain percentage of all electricity in the U.S. come from renewable sources by a target date — and that a specific percentage of that total come from solar PV; and the need to integrate energy efficiency with solar. Ideally, SHINE's army of installers and integrators will learn to profitably bundle energy-efficiency products and services with their solar systems, and ensure that solar-heated or -cooled buildings are adequately insulated.

Finally, SHINE will need the full participation and innovation of the financial services sector to create financing packages that will enable both systems purchasers and solar utilities a source of affordable capital.

MOVING FORWARD

As this report suggests, there is much work to be done. To help focus and further identify key pathways toward ensuring and accelerating our solar future, the Solar Catalyst Group recommends six projects or initiatives:

1 Demand-Side Survey

A buy-side survey to complement this current report to learn what it would take to get buyers to make large-scale, long-term commitments to solar purchases and installations — and, in doing so, to assess the potential market for solar at various price points.

2 Marketing/Messaging Plan

A study to prioritize target audiences and provide recommended marketing channels, outreach programs, marketing messages for each target audience — outlining calls-to-action and desired outcomes.

3 Utilities Study and Summit

A utilities-based Solar Opportunities Assessment Report — perhaps followed by an industry summit on the topic — that could identify key issues and barriers to mass deployment of solar by this sector. Participants would include utilities, regulators, and other key players.

4 Climate Change Study

A research project to evaluate and quantify the role that solar could play in helping to mitigate climate change. The study would help to quantify how much solar would be needed to play a central role in mitigating climate change, and over what period of time.

5 Super Solar Group Initiative

A major coordinating body to cross all the sectors involved with solar, including equipment manufacturers, marketers, installers, financing organizations, utilities, and regulatory bodies. This organization would be charged with pulling together the various groups and interests to coordinate and orchestrate/lobby for the advancing of common goals: pushing for standards, regulatory changes, technology developments, marketing, education, and training.

6 "Financing a Solar Future" Project

A research project to identify ways in which breakthroughs in financing could accelerate solar deployment. Such a project could include a survey of existing financial institutions serving the solar market and the most effective products they offer, and a look at what models from other industries — home mortgages, car loans, home-equity loans, and others – could be emulated or adapted for the solar market.

The three pathways presented in SOAR — Current Growth, Accelerated Growth, and Hypergrowth — represent critical, strategic choices to be made by the solar industry, political leaders, and citizens alike. They reflect nothing less than Americans' vision of their country and their world in the next quarter-century and beyond. Will our energy future — and all of the economic and quality-of-life impacts that stem from our continued reliance on fossil fuels and nuclear energy — depend, as it has to date, on a seemingly half-hearted effort to move to a more sustainable, renewable-energy future? Or will it reflect a strategic, ambitious, collective effort on the part of industry, government, and consumers to transform our energy future to fully exploit the untapped power of the sun and other renewable energy sources?

We believe, of course, that the latter is not only desirable, but critical to ensuring our economic, environmental, and social health. And we think the time is ripe to embrace and implement a collective vision to include solar energy as a pivotal part of our energy future — to move beyond the current pathway by making the rapid and dramatic growth of solar energy an urgent, national priority.

PART ONE:
THE STATE OF THE ART

What will it take to transform solar energy from a niche resource into a competitive, mainstream technology — and beyond, to serve society with solar's full promise? This Solar Opportunities Assessment Report, or SOAR, attempts to answer that simple but complex question and offer some possible pathways forward. It examines what is needed to grow the solar industry — incrementally into a thriving industry, as well as through bold, audacious measures that could dramatically accelerate the transition to a clean-energy future.

This report is divided into three key sections:

- **Part One** offers a brief overview of the state of solar energy markets, and why they have yet to reach critical mass.
- **Part Two** overviews the three principal "levers" that affect whether, and how, markets for solar energy can grow — and the three key strategies that, if employed, could significantly accelerate market growth for solar energy.
- **Part Three** examines one possible vision of what it would take to make solar energy a vital part of the energy future for America and the world.

SOAR is based on in-depth interviews with more than 30 leading authorities in the solar field to understand their perceptions and best thinking about the state of the solar industry, the challenges they face, and where the opportunities lie to break through those barriers to accelerate the growth of solar photovoltaics (PV). The interviews were complemented with additional research on and knowledge of the solar industry as well as with work done for our 2002 report *Bringing Solar to Scale*, which promoted a plan to dramatically ramp up the supply and demand for solar photovoltaics in a way that created a cost-competitive global industry in California.

Included in the interviews were CEOs and senior executives of leading solar equipment manufacturers, early-stage companies with potential breakthrough technologies, and system integration and installation companies. Also included were present and former government leaders in the field of renewable energy as well as consultants and representatives of solar trade organizations and think tanks.

The interviews and research were conducted by Clean Edge, Inc. on behalf of the Solar Catalyst Group (SCG) as part of its work to design programs that encourage the growth of solar markets. SCG is a nonprofit consortium of business, government, investor, labor, environmental, and community groups interested in catalyzing the solar energy portion of a renewable-energy future by creating a mass market for solar

Benefits of Solar

Solar provides more than just electricity. Here is a snapshot of some of solar's environmental, economic, and social benefits:

Job Creation	■ According to the Renewable Energy Policy Project (REPP), for every megawatt of solar PV, 35.5 jobs are created in manufacturing, installation, servicing, sales, and marketing
Environmental	■ Pollution-free source of electricity that can be sited close to demand, which limits the need for additional transmission and distribution power lines ■ Can play a critical role in mitigating the threat of climate change ■ Quiet operation
Reliability	■ PV systems last on average more than 25 years and require minimum maintenance
Economic	■ Fixed cost of electricity for life of system ■ PV systems are ideally suited for peak shaving applications – they produce the greatest amount of electricity when demand and pricing are the highest
Flexibility	■ PV systems are modular and expandable depending on demand
Energy Security	■ Reduced reliance on coal, natural gas, and other price-volatile energy sources ■ Reduced susceptibility to energy shortages, market manipulations, and other disruptions ■ Reduced stress on the existing grid
Public Health	■ Solar PV helps to ease pollution-related problems, such as those currently causing unprecedented increases in asthma in children

PV. SCG is a project of Co-op America, a national nonprofit organization dedicated to advancing market strategies to solve social and environmental problems.

SOAR focuses on the U.S. market, though it calls upon best practices and success stories from Germany and Japan, where solar has flourished, and from California, which leads the U.S. in solar installations. This is not to omit the potential for solar in the rest of the world, particularly in developing countries where solar can play a critical role in improving the lives of the non-electrified poor. However, we believe it is critical to the future of solar — not to mention to the future of the United States — that a vibrant and competitive domestic solar industry develop to reduce America's dependence on fossil fuels, reduce emissions of global warming gases associated with electricity production, promote greater energy security, and provide new jobs and business opportunities for Americans.

SOAR centers on the three key pillars of the solar industry: technology, policy, and finance. All three must work together in bringing the solar market (and most other technology markets) "to scale"

It is also important to note that our interviews and research were limited to solar PV — the process by which sunlight is converted into electricity — excluding other solar applications, such as solar thermal energy and solar-produced hydrogen.

SOAR centers on the three key pillars of the solar industry: technology, policy, and finance. It is commonly believed that all three work together in building the solar market (and most other technology markets) and that each of these represents a powerful lever that can be harnessed to bring solar "to scale" — that is, produced in suffi-

Methodology and Interviewees

The survey portion of this project consisted of phone interviews, typically about an hour each, with a cross-section of solar-industry leaders in the U.S. To facilitate candid responses, the interviews were conducted on a not-for-attribution basis, meaning that while individuals could be quoted in this report, the quotes would not be attributed to specific individuals.

The interviews addressed in detail several questions, deliberately broad and open-ended to stimulate ideas and brainstorming. Sample questions included:

- What are the market drivers and trends you see most affecting the solar PV industry?
- What major technological advancements in the industry do you see as being the most promising?
- In what parts of the industry do you see opportunities for dramatic cost savings?
- What are the key ingredients that will make solar cost-competitive with the existing grid?
- What types of market development or aggregation strategies would be most effective?
- What type of consumer/end user financing programs are most effective?
- How do government standards and regulatory issues affect the growth of the solar industry?

Organizations Interviewed

Manufacturers

ABB
BP Solar
Evergreen Solar
First Solar
Konarka Technologies
Kyocera Solar
Nanosolar
Nanosys
Raycom
RWE Schott
Sharp
Shell
SMA
Solaicx
Spire

System Integrators/Installers

Northern Power
PowerLight
Prevalent Power
SolarWorks
Solar Webb

Others

American Council on Renewable Energy
Greenstar
Interstate Renewable Energy Council
National Renewable Energy Laboratory
Power Shift
Renewable and Appropriate Energy Laboratory, UC Berkeley
San Francisco Public Utilities Commission
Solar Energy Industries Association
Solar Energy Research and Education Foundation
The Stella Group

cient quantity and efficiency as to be cost-competitive with nuclear and fossil-fuel-based energy sources, as well as with other renewable-energy technologies.

These three levers are intricately linked, though each works independently. In an ideal world, each of these levers could work in concert to catalyze a solar future, but pushing harder on any one of them could be sufficient to tip the scales toward cost-competitive solar. So, for example, while a technology breakthrough that dramatically lowers production costs could make all the difference, so could a significant scale-up in government purchases of solar PV systems, as could a major new corporate entrant with enough marketing clout to grow the solar market fast enough to build a critical mass of buyers and sellers.

In reality, no one company, technology, or policy decision is likely to make such a dramatic event happen — that is, there is no single “silver bullet” likely to bring solar to scale. Rather, it will take the concerted and concentrated efforts of numerous players and sectors to bring about the desired change.

The following pages describe the challenges and opportunities within each of these levers and the other components and efforts needed to break through existing barriers to growth. It also offers a vision of how a large-scale, well-orchestrated, and well-funded push could greatly accelerate solar energy's growth rate, helping ensure that solar reaches the full potential that it — and our nation and our world — deserves.

SOLAR'S PRESENT CHALLENGES

The dream of making solar photovoltaics a significant and viable clean-energy source has existed for more than a quarter century but has only recently begun to be realized. Over the past few years, solar PV has experienced dramatic growth as manufacturing costs have dropped and technology and efficiency have improved. For the past decade, solar and wind power have experienced double-digit annual growth rates, making them the fastest-growing new energy technologies in the global economy. According to Clean Edge research, the worldwide solar PV market, including sales of modules, system components, and installations, totalled $3.5 billion in 2002 and is projected to rise to $27.5 billion by 2012, assuming current market trends and technological developments.

While solar's global growth rate may seem impressive to some, the industry's installed base remains frustratingly small.

Annual global manufacturing output of solar PV modules has more than tripled in the past four years, from just over 155 MW of manufacturing output in 1998 to more than 560 MW in 2002. Japan, the global manufacturing leader, accounted for 252 MW in 2002, expanding fivefold from just 49 MW in 1998. And the U.S., the second-largest producer, represented 101 MW in 2002, nearly doubling from 54 MW four years earlier. (As the table below indicates, only about 30 MW of new solar PV were installed within the U.S. in 2001; the balance was exported.)

However, while solar's global growth rate may seem impressive to some, the industry's installed base remains frustratingly small. For example, new solar PV installations in the U.S. totaled just 32 MW in 2001. In contrast, some 1,700 MW of new wind-power capacity and more than 40 gigawatts (40,000 MW) of new natural-gas-fired power plants were brought online during that same period, according to the

Cumulative Installed PV Power, U.S. (1992-2001)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Off-grid	25.5	31.3	36.7	45.1	53.5	62.5	72.2	84.2	98.7	115.2
Grid-connected	6.0	7.0	8.2	9.7	11.0	13.7	15.9	21.1	28.1	40.6
Centralized	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Total	**43.5**	**50.3**	**57.8**	**66.8**	**76.5**	**88.2**	**100.1**	**117.3**	**138.8**	**167.8**

Source: International Energy Agency, 2001. Includes only installations greater than 40 watts.

Department of Energy's Energy Information Administration. Together, wind and solar generating capacity fulfill less than 1% of total U.S. electricity demand.

Among the key challenges:

- **Small quantities, high prices.** Solar's tiny contribution to overall U.S. energy production is directly linked to its small production scale. Most PV manufacturing facilities are relatively small — typically producing about 20 MW of modules a year or less — and unable to reach the economies of scale needed to bring costs down from the current range of $3 to $4 per wholesale watt to $1 to $2 per wholesale watt, the price at which solar starts to become cost-competitive with conventional grid-based electricity.

- **Chicken-and-egg dilemma.** As noted, new manufacturing capacity could help drive prices down dramatically, but construction of new PV plants won't take place without a strong, steady demand for the facilities' output. It's a classic chicken-and-egg dilemma: manufacturers haven't been willing to commit to increasing capacity — thereby driving down prices — without an assurance of an increase in demand. And buyers — especially large corporate, government, and institutional buyers — won't commit to long-term purchases without the assurance of lower prices.

- **Government R&D support.** Three decades of on-again, off-again government funding of solar research and development have frustrated private-sector companies, which thrive on the certainty that comes from consistent, long-term funding — the kind enjoyed for decades by the oil, coal, natural gas, and nuclear industries.

- **Financing.** The high cost of solar is compounded by a dearth of financing solutions, pricing solar out of reach of most users, whether residential, business, or government. Inadequate understanding of the low risk profile of renewable energy by lending institutions results in clean-energy investment opportunities being either ignored or financed with unfavorable terms. And bureaucratic government rebate programs can make for a daunting experience for buyers.

- **Government regulations.** A patchwork of regulations related to solar means manufacturers and buyers of solar systems must meet different requirements in each state. These include laws affecting net metering and interconnection, rebates and other financial incentives, building codes, and regulations affecting how utilities work with customers that install solar-energy systems.

- **Coordination.** There is very little coordination among companies, government agencies, the solar and building industries, or potential buyers of solar

systems. The result, for example, is that state and local governments often issue bid requests for substantially similar but slightly different solar systems, thereby eliminating the potential of pooling their purchases to cut prices.

- **Technology.** The technology is improving, though only incrementally. A number of breakthrough technologies wait in the wings that could make solar cheaper and more efficient. Unfortunately, many are hampered by companies who perceive the market for solar as too small for them to invest the funds needed to commercialize these innovations.

- **Standardization.** There is an enormous need to develop standardized, plug-and-play systems that would greatly reduce the complexity and cost of designing and installing a solar-energy system. This need is especially large in the building and construction trades, which could be a critical pathway for solar PV's accelerated growth, but where solar design and installation remains largely a custom, one-off component of many building projects, which raises costs and deters both contractors and customers alike.

- **Education.** Many of these problems are made worse by the lack of understanding about solar on nearly everyone's part: business, government, and individual consumers.

None of these issues stands in isolation; nearly all are connected with the others. Solving them means looking at the issues both individually and holistically.

SOLAR'S FUTURE GROWTH: THREE PATHWAYS

How fast can the solar industry grow? Here are three different pathways for the growth of solar between now and the year 2025.

Pathway One: Current Growth

This pathway, while the least ambitious of the three, isn't altogether undesirable: solar PV sales and installation are currently growing at 25% to 30% annually, even in a depressed economy, and will likely continue to expand by an average 24% annually over the next two decades. Indeed, as we report later on, many of those we interviewed are quite comfortable with these growth rates and the resulting efficiencies and economies of scale the industry has been achieving. These individuals see faster, disruptive growth as exactly that: uncomfortably disruptive to their companies and sector. For these individuals, maintaining or gradually growing the status quo — the patchwork of financial incentives, technology improvements, and market developments — will eventually lead to the vibrant, profitable industry they envision. However, sustained growth is not guaranteed under this business-as-usual scenario: It is

possible for any number of forces to slow or even stop PV's current growth, from markets that become saturated at current prices to inadequate or disappearing government support in the U.S. as well as Japan and Germany.

Pathway Two: Accelerated Growth

Much of this report focuses on this second pathway, detailing ways to roughly double projected PV installations by 2025. There is no shortage of ways to do this: something as straightforward as standardized, affordable financing for end users could by itself double installations, according to some estimates. Most of our interviewees saw this pathway as both desirable and achievable in the near to mid term. Many of the recommendations in this report are geared toward fulfilling this scenario.

Pathway Three: Hypergrowth

Later on in this report, we've stepped back to proffer a vision of what would be required for an ambitious, audacious "man-on-the-moon" type of goal for PV. This, of course, is a reference to President John F. Kennedy's 1961 proclamation that "that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth" — a feat that seemed impossible at the time but which was, in fact, achieved in 1969. We have outlined in this report one such vision, referred to by the acronym SHINE, for the United States.

Projected PV Growth Under Three Pathways

	Current Growth	Accelerated Growth	Hypergrowth
Compound annual growth rate	24%	28.5%	38%
Cumulative Installed MW in 2025	35 gigawatts	70 gigawatts	290 gigawatts
Electricity Production Equivalent in 2025	63,000 gigawatt-hours	126,000 gigawatt-hours	522,000 gigawatt-hours
% of Projected U.S. Electricity Consumption in 2025	1.2%	2.4%	10%

Assumes each kilowatt-hour installed provides an average of 1,800 kilowatt-hours a year. Source: International Energy Agency, 2001. Includes only installations greater than 40 watts.

Like Kennedy's vision, which was buttressed by an array of well-funded partnerships among many players, SHINE would need to bring together a wide range of interests — industry, government, nonprofits, labor, builders, utilities, and others — to collaborate on a vision that could, if successful, grow solar PV installations significantly over the current path so that solar fulfilled a significant portion of U.S. energy needs by 2025. While the SHINE vision was not discussed directly within our interviews, it is clear that some players in the solar industry believe that it will take such a grand vision to make solar competitive with other forms of energy, and to create a truly world-class solar industry in the U.S.

Solar Growth Projections In 2002, the U.S. had 240 megawatts of cumulative installed PV, a fourfold growth from 1994. During this period, the industry experienced an average compounded annual growth rate (CAGR) of 24%. Even at this high

For solar to fulfill 10% of U.S. electricity consumption in 2025 would require 38% compound annual growth — a truly Herculean effort, but an achievable one, as the PC industry demonstrated.

rate of growth, PV still accounted for a mere 0.001% of all U.S. electricity consumption in 2002.

In the chart on the preceding page, we look at three different scenarios for PV growth rates through 2025, based on the Current Growth, Accelerated Growth, and Hypergrowth pathways described in this report. It shows that if the current rate of growth could be sustained for more than two decades, it would result in 35 gigawatts (35,000 megawatts) of PV installed in the U.S. by 2025 — just over 1% of total U.S. electricity consumption in 2025 (estimated at 5,252,000 gigawatt-hours by the federal Energy Information Administration).

What would it take to double that, to 70 gigawatts — about 2.4% of U.S. electricity needs in 2025? That would require the CAGR to rise to 28.5% between now and 2025. And to reach 290 gigawatts — 10% of U.S. electricity consumption in 2025 — would require a CAGR of 38%.

We know of only one historical precedent for sustaining such large growth rates over such a long period of time. The personal computer industry experienced a CAGR of 38% from 1980 through 2000, according to the *Computer Industry Almanac*. This shows that such high growth rates, though rare, can be sustained under the right conditions.

For solar, the "right conditions" include the projected global energy demand growth and the nearly unlimited need for new energy supplies to replace decommissioned fossil fuel-based plants. They also could include political and environmental perturbations or pressures that could lead to a strong demand for alternative energy sources.

Bottom line: For solar to fulfill a significant portion of America's energy future would require a truly Herculean effort — but an achievable one, as the PC industry demonstrated.

PART TWO: ACCELERATED GROWTH

THREE KEY LEVERS

As stated earlier, three "levers" — technology, policy, and finance — play a key role in building markets for any technology, and solar is no different. For solar energy to move beyond "business as usual" and to reach critical mass, it will be necessary to pull on each of these levers. Following is an examination of the three key levers and how they may be used to transform the solar market.

TECHNOLOGY: PROGRESS, BUT NO BREAK-THROUGHS

There are two sets of technology problems to solve in order to reduce the cost of buying, installing, and operating a solar PV system:

- manufacturing of the cells and modules, and
- the "balance of system" components — inverters, interconnection devices to the grid, two-way meters, and racking systems, as well as installation techniques.

A series of developments have helped push down the cost of PV modules at a steady pace — from $30 per peak watt in 1975 to about $3 or $4 today.

For three decades, people eager to see PV adopted in greater numbers have held out hope that a technological breakthrough would dramatically lower purchase and installation costs and help bring solar to scale. In large part, they are still waiting. Today's solar cells and balance-of-system components employ substantially the same technology as those made ten or twenty years ago. Much as they have since the 1970s, major technological breakthroughs in solar remain just over the horizon.

This is not to say that solar technology remains unchanged. Indeed, a wide range of developments have helped push down the cost of PV modules at a steady pace — from $30 per peak watt in 1975 to about $3 or $4 today. But these changes have been largely incremental, the result of a series of small but continuous improvements in manufacturing efficiencies and in the performance of the cells themselves. Similarly, there have been few major advances in balance of system components and installation techniques. At the current rate of technological change, some of the experts we interviewed believe that solar energy will continue to have a difficult time competing with conventional energy sources, as well as with other renewables, such as wind, biomass, and geothermal energy.

Things could change. While nearly all we spoke with expressed deep skepticism about impending breakthroughs — nobody that we interviewed expects a technological "silver bullet" in the foreseeable future — impressive developments are underway in laboratories in the U.S. and around the world. More than a score of early-stage companies have made claims that they will soon leapfrog existing technologies and could

Some believe breakthroughs are not even necessary. They point to the fact that using existing technology, costs are coming down much faster than they ever thought possible.

bring the price of solar modules to under $1 per watt; a price that could eventually bring total installed system costs to under $3 per watt. At the same time, a number of companies are working on so called "plug and play" systems that can be installed more quickly and easily with less expensive balance of system components including racking and inverters.

Are Breakthroughs Necessary?

Such potential notwithstanding, solar veterans we spoke with downplayed the importance of breakthroughs. As one manufacturer said, "We don't really believe in disruptive technology happening. We're just not willing to cross our fingers and hope that the big breakthrough happens. The solution has been just around the corner for 30 years."

Some believe breakthroughs are not even necessary. They point to the fact that using existing technology, costs are coming down much faster than they ever thought possible. As a result, for the near term, respondents told us that the market would continue to be dominated by crystalline silicon, the incumbent technology, coupled with continued cost reductions from incremental gains in manufacturing processes and cell efficiencies.

The key to lowering PV costs, in this world view, is to scale up manufacturing and improve manufacturing processes — for example, automated manufacturing, more efficient use of silicon, and technologies that more efficiently apply a layer of silicon to a substrate. Equally important is to reduce the cost of installation and the balance of system through scaling up production of components like inverters, developing standardized "plug and play" systems, and implementing massive solar installation training programs and greater cooperation between the solar and building industries.

Key Technology Barriers and Challenges

- **Incremental improvements may not be enough.** Although increases in manufacturing efficiency and economies of scale are leading to PV cost reductions, such incremental advances are not bringing down prices fast enough to make PV cost-competitive on a large scale. Not surprisingly, advocates of emerging PV technologies say that we must move beyond crystalline silicon-based technologies to break through one key barrier: the underlying cost of the main ingredient, silicon. One start-up entrepreneur said, "The silicon-based solar cells are essentially in diminishing returns. All the advances that have happened have limited impact [on costs], in the 20% range. If you look at the DOE industry road map, we're talking about a time frame of 2020 to get another 2X in cost reductions. That's a nice trend, but it's not clear how it's going to become a reality just through manufacturing

improvements. We're looking at leapfrogging more than that kind of improvement in a much shorter time."

Some experts disagree that silicon is a barrier to lower cost PV. While acknowledging that the silicon raw material used in PV cells is currently a considerable part of manufacturing expense, they argue that increased demand for the material will lead to new and cheaper ways of processing silicon, one of the world's most plentiful resources. Currently, the PV industry relies primarily on scrap silicon from computer chip manufacturing. With greater demand for PV-grade silicon will come competitive processing and supply chains that will lead to lower cost product.

One installer told us, "Performance and reliability is key. We saw that plastic and other non-glass substrates degrade within 10 years. Even if you bring a fantastic product to market at fantastic price points, there's another field-testing phase that you have to do."

- **New technologies are unproven and unreliable.** Most much-promised and hyped breakthroughs remain unready for prime time. Thin-film technologies, for example, a technology with great promise to reduce PV costs, are plagued by cell-degradation and low-efficiency issues; already some installers have had to replace installed thin-film panels that have failed or performed unsatisfactorily. Even if new PV materials come to market at significantly lower prices, such concerns about performance and reliability will slow adoption.

  Established industry players also told us that they are concerned that if the new technologies do not live up to marketing claims and if these manufacturers go out of business, the reputation of the entire industry may suffer. "Who will honor the industry standard 25-year warranties?" one asked.

This skepticism presents new, non-silicon market entrants with an enormous hurdle. As one installer told us, "Performance and reliability is key. We saw that plastic and other non-glass substrates degrade within 10 years. Even if you bring a fantastic product to market at fantastic price points, there's another field-testing phase that you have to do."

- **Inadequate government R&D support.** Many interviewees pointed to increased government support for R&D — especially for early-stage companies trying to commercialize new PV technologies — as critical for the industry. But current federal government funding may be best characterized as inconsistent.

  The amount of financial support allocated to solar has been a perennial complaint within the solar industry. Perhaps more troublesome, as our interviews found, is the slow pace at which government labs — such as the Energy Department's National Renewable Energy Laboratory — can operate. The pace can frustrate entrepreneurs racing to develop technologies before their start-up funds run dry (and before their competitors beat them to market).

Yet they need government testing to certify a technological breakthrough — a mandate of venture capitalists waiting in the wings to fund the company once it has a certifiable breakthrough.

Another troubling complaint is that government labs tend to be more helpful with established, incumbent players — the ones that, arguably, need government funding and assistance the least. Said one entrepreneur: "The complaints are common that the government has a charter to help industry, but they have no charter to do it fast. From a small-company perspective, they clearly want to focus on the guys with the deep pockets. It's much easier for Shell or BP to get a grant than it is for a start-up."

In addition to support for developing new PV cell technology, balance-of-system developers need help bringing new products to market that will make deployment easier and less expensive. Also, established players in the industry continue to need assistance improving their manufacturing efficiencies and scaling their production. With limited government dollars for the industry as a whole, there are many neglected areas in solar R&D.

- **The perceived market may be too small** — at least at existing solar costs and those projected for the foreseeable future on the current growth path. One common belief we heard repeatedly is that only one major PV manufacturer currently is making a profit from PV module sales. (We were unable to confirm this.) All the others have various reasons for competing, this reasoning goes, including a belief in the market's long-term potential, but PV currently is a loss leader for them. Understandably, many of these same manufacturers, and others on the sideline, are hesitant to make the

PV Cost Projections: Running the Numbers

There are many factors that affect the projected costs of solar PV installations, measured on a cents-per-kilowatt-hour basis. These include the type of installation (industrial, commercial, or residential), average hours of daily sun exposure, the cost of capital, and the payback time. Calculations can vary widely, depending on which of these factors are included, and what values are assigned to each.

As evidenced in the accompanying table, when the cost of an installed watt drops below the $3 watt level (based on pure installation costs or after rebates), prices will start to become competitive for a larger range of residential, consumer, and industrial applications, especially in those areas with high rates and/or time of use pricing.

	EQUIVALENT COST PER KILOWATT-HOUR	
COST PER INSTALLED WATT	RESIDENTIAL	COMMERCIAL/ INDUSTRIAL
$8	$0.37	$0.25
$6	$0.27	$0.18
$4	$0.18	$0.12
$3	$0.14	$0.09
$2	$0.09	$0.06
$1	$0.05	$0.03

Assumes a 15-year home equity loan at 7% interest (residential), including federal tax deductions for an average household earning $80,000 year, or a 7-year loan at 6% interest (commercial/industrial); a system producing 1,800 kilowatt-hours per year per peak watt; a 25-year system life; and an annual degradation of 1%. Does not include tax credits, buydowns, or other incentives.

needed investment to scale up R&D — or even to enter the market — because they do not see a big enough upside potential that will yield worthwhile returns on capital-intensive technology investments. It is easy to understand this view considering current PV prices, but many believe that with pricing closer to $3 per installed watt – an attainable goal within the next 5 years, according to leading solar experts – a profitable mass market will emerge.

Key Technology Opportunities and Pathways

- **Improving economies of scale.** The size of production facilities could be a key to lower manufacturing costs, said several respondents. One manufacturer said, "PV technology has reached a maturity level where the size of factories is the major issue. You need a 30-50 MW factory in order to compete. These economies of scale are critical unless there is something really unique in the technology." Others suggested that co-locating a series of 30-50 MW plants, or building 100 MW-plus size plants, could capture even more cost-efficiencies. "Every doubling of cumulative production has led to an 18% decrease in cost, so there are some economies of scale in PV manufacturing that are important factors in driving down prices," said one manufacturer.

- **Improving "balance of system" technologies.** The components of a PV system beyond the cells themselves, including inverters, interconnection devices to the grid, two-way meters, and racking systems — known collectively as the "balance of system" or BOS — are ripe for efficiency improvements and technology breakthroughs. Balance of system components and installation account for roughly half of total system costs. So, less expensive

PV Technologies Under Development

- **Nanotechnologies:** Various start-up companies are trying to commercialize nanoscale technologies for multiple applications, including grid-connected and building-integrated markets. From inorganic semiconductor nanocrystals to self-assembling nanostructures to dye-sensitized nanometer-scale crystals, all are attempting to produce lightweight, flexible, and low-cost cells in high volume; some plan to use roll-to-roll manufacturing processes, which directly cut costs.
- **Sputtering:** Borrowing technology used to place a magnetic coating on computer disk drives, a couple of early-stage companies are adapting this process for manufacturing solar cells. These techniques use automated, continuous-flow processes for placing a thin coating of solar-collecting material, like CIGS thin-film cells, on cheap, thin, lightweight substrates. The goal is to produce cells with the efficiencies of silicon but at a quarter of the cost.
- **New silicon-based technologies:** A few companies are building on silicon's proven track record for high durability and efficiency with new manufacturing approaches that require significantly less of this high-cost material. One company is using tiny silicon balls attached to aluminum foil substrates to make its low cost, flexible sheets of cells. Another startup has a process that leverages advanced deposition of low-cost silicon feedstock in a continuous flow process.
- **Organic semiconductor thin-film:** One start-up is working on depositing conductive polymers over inexpensive Mylar film. They are hoping to make a thin-film organic semiconductor device that uses the principles of polarization to organize incoming photonic energy and then change it into electricity.
- **Concentrator cells and collectors:** Other companies are using optics to magnify solar energy onto cells — and one company claims to be using mirrors to concentrate solar energy to a stirling engine which then generates electricity.

Glossary of Terms

- **Balance of System:** Refers to components of a PV system beyond the cells themselves, including inverters, interconnection devices to the grid, two-way meters, and racking systems.
- **Feed-In Laws:** Allow solar customers to sell excess power that they have generated back into the grid.
- **Interconnect Standards:** National technical standards for connecting distributed generation equipment to utility grids.
- **Net Metering:** Allows for measuring the difference between the electricity supplied by a utility and the electricity generated by a customer-generator, which is fed back to the utility over the applicable billing period. The meter is allowed to register the flow of electricity in both directions, and only the net amount is billed (or credited) each month.
- **Renewable Portfolio Standards:** Requires that all energy marketers have to have a certain percentage of renewables in their electricity mix.
- **System Benefit Charges (Public Benefit Funds):** Like telephone and airline fees that support building and upgrading the entire network, SBC are fees placed on electricity companies or customers to fund renewable energy projects with public money.
- **Time-of-Use Rates:** Real time pricing reflects demand. When demand is greatest (usually between noon and 6 p.m.), pricing is the highest.

components and installation techniques that are easier and less time consuming could dramatically improve solar PV's cost competitiveness.

Inverters — which convert solar's direct current (DC) into the alternating current (AC) used in nearly all households and businesses — were referred to as the Achilles heel of PV systems because of their high cost and low reliability. As one solar expert explained, "Until inverters can overcome quality issues and reliability, we probably shouldn't even be talking about the growth of the PV industry."

Industry experts told us they anticipate a number of new "smart" inverter designs as well as new entrants in the next few years — including, possibly, manufacturers of appliances designed to work directly off solar's DC electricity, improving solar's efficiency by averting the need to "invert" the electricity into AC — with some big global players — possibly including giants like Philips, ABB, and General Electric — reportedly looking to enter the market. While such companies could dominate the market if they entered, some believe the market may be too small for them to get involved. Still, any of these companies' entry would likely lead to cost reductions and improved liability. One expert likened the potential effects of a large player entering the inverter market to Sharp entering the PV module market, a move that led to prices dropping 15%. In fact, Sharp recently introduced its first inverter into the marketplace.

Decreased government funding, a reluctance by established players to commit funds for new research, and relatively meager venture capital investments in the earliest-stage solar start-ups reduce the chances that the market will see a technological breakthrough in the near-term.

- **System integration and packaging.** Technology breakthroughs also will come from integrating and packaging the systems. Despite experts' general disregard for leapfrog breakthroughs, most agreed that the greatest area of technology improvement is in creating packaged systems — with inverters, racking, and other balance of system components — and plug-and-play systems that are quick and inexpensive to install. PowerLight was the first industry player to do this for mid- and large-scale systems. In 2003, RWE Schott launched a competitive system called the SunRoof FS, and Sharp introduced a plug-and-play system called Sunvista that holds great promise to bring down the cost of residential systems. A number of those interviewed hoped, and expected, that the large module designers and manufacturers

would get more involved in creating these packaged systems and in training installers.

- **Technology and manufacturing breakthroughs.** As the box on page 22 indicates, several new technologies being developed by nearly a score of companies hold promise to dramatically decrease the cost of solar manufacturing. We heard a great deal from interviewees about the potential of roll-to-roll technology and other automated, continuous-flow manufacturing processes to dramatically lower cell production costs, especially of thin-film modules. However, they also noted that while some of the most promising technologies might indeed lower the cost of cells, they also are likely to produce cells with lower efficiencies than current cells. As one manufacturer pointed out, "When you put whole equation into place, you have to have efficient cells. Half the efficiency of the current production would not be attractive, even if it was 25% lower in cost." He went on to say, "It turns out that one of the highest costs for deploying a solar system is installation. Installation costs go up as you have inefficient module, like thin-film. More wiring, more time, more installation costs."

- **Building-integrated systems.** According to many respondents, building-integrated PV (BIPV) represents a critical technological opportunity in the near-term. The fastest way to grow this market, they said, is for manufacturers to more actively educate and collaborate with designers and architects so that BIPV becomes a standard part of new construction. While a small but growing number of homebuilders are using PV roofing shingles, experts point to the potential of other applications in construction. Said one: "There is a need for more PV applications that also enhance the structural aspects of a building. The market needs more systems, like PowerLight's offerings, that have extra benefits like insulation and building-integrated value."

- **Integrating solar with energy efficiency technologies.** There are numerous energy-efficiency technologies, including improved insulation, windows, lighting, and appliances, that can dramatically cut energy consumption. When these technologies are bundled with solar systems the initial total cost is greater, but the payback is faster. It is easiest and cheapest to integrate these two technologies in new building construction, as opposed to retrofitting existing buildings.

Conclusion: Technology

A number of promising PV technologies under development, if successful, could dramatically lower costs for PV and lead to huge growth for the sector. While most entrepreneurs trying to commercialize these technologies anticipate having their products

in the market within the next three years, every existing manufacturer and industry observer told us that the challenges of scaling these processes will take longer than the start-ups imagine. In the meantime, expect incumbent manufacturers to continue making incremental process improvements and find ways to lower total installed costs thanks to balance-of-system advances and new installation techniques.

Decreased government funding, a reluctance by established players to commit funds for new research, and relatively meager venture capital investments in the earliest-stage solar start-ups all reduce the chances that the market will see a technological breakthrough in the near term. Like other technologies that have overcome development hurdles and been widely adopted — such as satellite televisions, cell phones, and wind turbines — PV technology will continue to improve and steadily drop in cost on its own, but it will be a slow, incremental evolution. As it has with other technologies, a major government-sponsored R&D push could greatly accelerate the process.

See Appendix Two for additional information on technology development and adoption paths.

POLICY: THE CRITICAL NEED FOR GOVERNMENT SUPPORT

The solar PV industry is significantly impacted by government policies and regulations and, in many cases, a lack thereof. Like conventional energy sources such as coal, oil, and natural gas, solar is dependent on supportive policies and initiatives at the local, state, and federal levels. The simple truth is that no grid-based solar market in the world is presently viable without robust and consistent government support.

Our research shows that in some regions of the U.S., a number of key state programs are currently the most significant drivers affecting the growth of solar PV. These programs include:

- rebates and subsidies funded by system benefit charges, also known as public benefit funds;
- state-based renewable portfolio standards (RPS);
- net-metering and interconnect standards; and
- state and local government procurement programs.

Our survey found a majority of respondents stating that consistent, long-term government policies, regulations, and incentives are critical to the healthy growth of solar PV markets.

Our survey found a majority of respondents stating that consistent, long-term government policies, regulations, and incentives are critical to the healthy growth of solar PV markets. Not surprisingly, countries like Japan and Germany that have implemented innovative and supportive national policies lead the world in both PV manufacturing and installations. (See Appendix One for additional information.) In 1996, Japan accounted for less than a quarter of global PV production; by 2002, three of the top five PV manufacturers were Japanese, and Japan accounted for nearly half of global PV module production.

Few solar markets in the world today are cost-competitive without government support, except for niche markets such as off-grid power for rural electrification, water pumping, and emergency signs and phones.

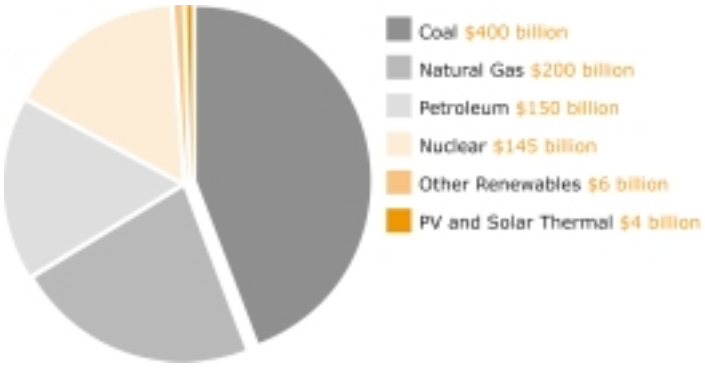
In the U.S., a lack of consistent federal support has resulted in a fragmented, regional market. This has created a unique situation in which certain states, such as California and New York, see the bulk of solar installations, while states with limited or inconsistent policies see little or no PV development. The lack of a federal policy also has contributed to the U.S. losing its former leadership position in the solar PV manufacturing arena, ceding, for the moment, yet another industry it spawned to the Japanese.

While policy does play a significant role, our research reveals that industry insiders believe there is no one solution. Instead, respondents overwhelmingly indicated that it would require a concerted, multi-pronged policy effort, including rebates, interconnect and net-metering standards, and other programs. As one respondent pointed out: "North Carolina has some of the best PV tax credits in the country and low-interest loans for commercial facilities [for PV]. But the state doesn't have net metering or good interconnection standards. As a result, there's virtually no PV installation happening in North Carolina."

In the U.S., policies to help grow the solar PV industry currently are the domain of forward-thinking states and communities that have coordinated and implemented a range of effective programs. Nevada, for example, has implemented an RPS targeting 15% renewable energy by 2013, with 5% of that amount designated for solar. Our research shows that until there's a change in direction at the national level, state and regionally coordinated policy efforts such as these will remain the key driving forces. There is a significant need for increased cooperation among states and local jurisdictions, both regionally and nationally. Specific recommendations are included later in this report.

Federal Support for Energy Sources, 1943-1999 (US$ Billions)

In the U.S., all major energy sources have received combined government support totaling trillions of dollars over the past five decades. The question of government support for solar is less about costs and more about political will.



Source: PowerLight Corp., based on research by Renewable Energy Policy Project, Research Report 11, Federal Energy Subsidies: Not All Technologies Are Created Equal, MRG & Associates, Madison, WI, July 2000.

Few solar markets in the world today are cost-competitive without government support, except for niche markets such as off-grid power for rural electrification, water pumping, and emergency signs and phones. Countries with proactive policies and government and industry cooperation are starting to see significant results that may help make PV competitive with conventional grid electricity. In Japan and Germany, for example, long-term

commitments and effective policies have helped bring the total installed costs of residential grid-tied PV systems to close to $6.50 per watt (approaching price parity with Germany's and Japan's expensive grid electricity), whereas comparable residential systems in the U.S. run between $8 and $12 per watt. This price gap is significant and represents the critical difference between limited penetration and wider adoption.

As installed system prices fall below the $4-per-watt mark with limited or no subsidies, many experts agree that we'll begin to see a thriving industry in regions where electricity prices (including the costs of both energy and transmission and distribution) are high — say, 18¢ or more per kilowatt-hour. This includes much of Europe, Japan, and various regions in the United States. When solar falls below $3 per watt installed with limited or no subsidies (approximately 9¢-14¢ per kWh), PV will reach an important tipping point that will make it cost-competitive in most sunny regions of the world. And when solar falls below $2 per watt installed with limited or no subsidies (approximately 6¢-9¢ per kWh) it will become competitive with grid power in

Filling the Void

In the absence of federal leadership on solar, a number of states have worked to fill the void with a range of policies and incentives. Below are select state clean-energy policies.

STATE	SOLAR PV REBATES	SYSTEM BENEFIT FUND	RENEWABLE PORTFOLIO STANDARD	NET METERING	TAX CREDITS
CA	Numerous programs from the California Energy Commission (CEC), Public Utilities Commission, and municipal utilities. Largest PV program, by the CEC, offers $3.80/watt rebate.	$540 million for a range of renewable energy programs.	20% renewable energy by 2017.	√	√
MA	Various programs including a $5/watt buy-down with 70% paid upon installation and the remaining paid based on system performance over 3 years.	$150 million over five years.	4% renewable energy by 2009.	√	√
NJ	New Jersey Clean Energy Program with incremental rebates based on size of system.	$358 million over three years. 25% for renewable energy sources and 75% for energy efficiency.	4% renewable energy by 2008; 20% by 2020.	√	√
NV	Nevada Power Company oversees a small pilot project providing residential rebates of $3/watt (up to a maximum of 1 kW).	None	15% by 2013, with 5% from solar.	√	√
NY	Various programs, including $4 - $5/watt buy-down.	$975 million budget over eight years for clean-energy development.	25% renewable energy by 2012.	√	√
PA	Various programs.	Approximately $100 million across four utilities.	2% renewable energy by 2001, with .5% annual increase thereafter.	√	

Sources: DSIRE Database, ACRE Conference 2003, and Clean Edge, Inc.

many regions. Based on our research, and on our survey of experts, government policies make a critical difference in reaching the goal of cost-competitive solar.

Key Policy Barriers and Challenges

On the policy front, the solar industry faces a number of key challenges in the U.S. They include:

While a few municipal utilities have taken a leadership role, such as the Los Angeles Department of Water and Power and Sacramento Municipal Utility District, few other major utilities, whether publicly or investor-owned, have yet embraced solar.

- a lack of federal policy and regulations;
- few, if any, large, long-term government incentives and commitments;
- a patchwork quilt of state-level programs threatened by state budget woes;
- subsidy programs that artificially inflate prices; and
- resistance from utilities and other incumbent players.

Let's take a closer look at each of these.

- **Lack of federal policy and regulations.** The lack of national governmental leadership on solar means that the U.S. has no consistent, widespread policies regarding net metering, interconnection standards, and other key regulatory and infrastructure issues needed to propagate solar markets. The general consensus among survey participants is that the federal government has been missing in action from the solar policy landscape. As one systems integrator noted, "The federal government has a huge role to play, but they haven't stepped up yet." (One leading manufacturer quipped that this lack of federal policy and coordination "has much more bearing on the graying of my hair" than just about any other issue.)

- **Few, if any, large, long-term government incentives and commitments.** The lack of long-term government incentives and commitments in the U.S., especially at the national level, was also mentioned as a significant barrier. These include the lack of consistent coordination and support at the national, state, and regional levels for a range of incentives and programs including:

    - **Technology development** (R&D, tech transfer, commercialization assistance, etc.);
    - **Regulatory** (building codes, net metering, interconnect standards, etc.); Finance (low-cost government backed mortgages/loans, tax credits, end-user subsidies, etc.); and
    - **Market development** (aggregated government procurement, market coordination efforts, educational campaigns, etc.).

Respondents said the key is not merely implementing such critical programs, but making them consistent and long-term. Many industry experts pointed to the wind production tax credit, which must be re-approved by lawmakers every two years, as an example of shortsighted clean-energy policy implementation. “We need consistent policies to maintain steady growth. Look at the wind industry and how any time there’s uncertainty around the production tax credit it [negatively] affects development,” explained one industry expert.

According to a major PV manufacturer, “Japan will be standing on its own feet in two to three years because government and industry have been working together.” According to this respondent, the U.S. will have to embark on a similar large, long-term commitment to reach success. Until the U.S. sees more long-term commitments at federal, state, and regional levels, it is unlikely to provide the right signals to industry to move beyond low-scale, high-cost production. Sustained, orderly growth of the PV industry will require a high-level of public-private cooperation and coordination — and long-term governmental commitments to policy, procurement, and other enabling roles.

- **A patchwork quilt of state-level programs threatened by budget woes.** Survey respondents said that the current market requires that manufacturers and installers be well-versed in intricate details within every region. As one systems integrator/installer noted, “There really is no national market in the U.S. today, only state-based ones. We are all national businesses focused on regional opportunities.” This patchwork quilt of state-level programs means that while there is diversity, there is limited market order.

  And many of the state programs, including subsidies and tax credits, are at the mercy of state budgets that have been decimated in recent years. Some of the state benefit funds have been raided to help cover general budgetary shortfalls — raising alarm within the solar industry.

- **Subsidy programs that artificially inflate prices.** While more than half of all respondents felt that government-backed rebates or buy-downs were an important tool in building PV markets, many were supportive with “reservations.” Subsidies are seen by many in the industry as a double-edged sword. As one installer succinctly stated: “If subsidies go away, we go away.” Of equal concern, however, is that subsidies can inflate pricing by rewarding high costs across the entire value chain, from manufacturing to balance of system and installation. One manufacturer, reflecting this belief, noted that “Some [rebate] programs are hurting industry... by not encouraging manufacturers to go cheaper.” If set up poorly, subsidy programs can have a nega-

tive impact on system and installation pricing, keeping prices artificially high.

- **Resistance from utilities.** One of the biggest challenges facing the solar PV industry today is the lack of current support by most utilities. While a few municipal utilities have taken a leadership role, such as the Los Angeles Department of Water and Power and Sacramento Municipal Utility District, few other major utilities, whether publicly or investor-owned, have yet embraced solar. And some utilities have set up roadblocks in the form of lobbying against pro-solar policies and initiatives, uncooperative positions toward net metering and interconnect standards, and other oppositional stances that view solar as a detriment rather than as an opportunity.

  As a solar module manufacturer put it, "Regulatory guidance is required, because it's not always in the utilities long-term interest to have people produce their own power." This requires devising programs that reward utilities and let them participate in PV development, ownership, and leasing. An industry expert noted that "The role of the utilities seems critical. They can either facilitate or block this."

Key Policy Opportunities and Pathways

There is a wide array of government policies and initiatives that can help the U.S. regain its leadership position in solar PV. We've gathered key data from our industry survey, as well as lessons culled from the experiences of Japan, Germany, and California to gain a better understanding of how to turn obstacles into opportunities. Following are some of the key policies and programs that could help move solar from miniscule to mainstream.

Declining subsidies provide the right message to manufacturers and installers, helping to foster cost-competitive product offerings and less dependence on government support. As one large PV manufacturer said, "Incentive programs should be focused on bringing costs down, not inflating them."

- **Declining subsidies.** Subsidies are a critical component in today's policy landscape, but they need to be carefully designed in order not to send perverse signals to the marketplace. As noted above, if designed poorly, subsidies can actually inflate pricing.

  Declining subsidies (those that decrease over time) have proven an effective strategy that can bring prices down by increasing demand for solar. Japan, which has provided residential solar PV subsidies for nearly a decade, has decreased subsidy payments from 50% of the system's cost in 1994 to a fixed rate of approximately $1,000 per kilowatt today. California has recently started to implement a declining subsidy as well, from $4.50 per watt in 2002 to $3.80 per watt today. California plans to continue to decrease its subsidy by 20¢ every six months.

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dependence on government support. As one large PV manufacturer said, "Incentive programs should be focused on bringing costs down, not inflating them."

- **National standards for net metering and interconnection.** Most respondents felt that states and municipalities are best suited to designing effective solar PV policies and initiatives (due to the localized nature of solar energy, including regional energy costs, building codes, and solar incidence), and that there's also a clear need for the federal government to play a key role. On the top of most respondent's federal policy wish-list is the development of national standards for net metering and interconnection. Standards are critical in guaranteeing that there's a level playing field for distributed generation of solar power and would play a critical role in furthering the development of robust markets.

- **Feed-in laws.** Germany, which implemented feed-in laws (which allow solar customers to sell excess power back into the grid) at the core of its solar program, has helped demonstrate how enabling customers to sell excess power to utilities can stimulate PV's market growth. Japan, which has focused more on subsidy programs to grow its solar industry, also has feed-in laws that have enabled solar PV owners to sell back unused power at prevailing retail rates

  Many survey respondents felt that this ability would similarly empower U.S. consumers and could be one of the greatest impetuses for solar PV market growth as witnessed in both Japan and Germany. To make this a reality, federal, state, or regional entities would need to require utilities to implement feed-in programs via policies, regulations, and equipment upgrades.

- **Time-of-Use Pricing.** Implementation of time of use rates could have a major impact on the adoption rate of solar PV. Time-of-use pricing reflects the cost of energy when it is most scarce and in highest demand — during peak hours. Since solar power is often concurrent with peak demand, it could provide a significant price offset in those regions that implement time of use pricing.

  By combining new rate structures with the ability to sell back to into the grid (feed-in laws, see above) would provide an even greater incentive to prospective solar PV buyers — in effect leveling the playing field and helping to turn energy consumers into energy producers.

- **RPS with Solar "Carve-Outs".** Renewable portfolio standards have become a popular way for states and other government entities to implement clean energy targets and strategies. California, for example, has an RPS tar-

Guaranteed, bulk purchase orders, over a period of 3-5 years, provide companies with the confidence they need to invest in new plants and facilities and for installers to train and invest in staffing.

get of 20% by 2017; New York's target is 25% by 2010. In both cases, the states are hoping to double their current level of renewable energy use by major utilities in the state.

However, relatively few new solar PV installations have resulted to date from RPS, because in most situations wind power, geothermal, and biomass provide lower-cost solutions. For solar to benefit would require that each RPS require that a portion of the standard's target be met with solar installations. Arizona, Nevada, and New Jersey, for example, have implemented such policies, and other states are looking at similar "carve-outs" for solar. This will help to ensure that solar PV is included in the RPS mix.

Another key issue: most RPS policies are targets, not mandates. For an RPS to work, it may require that governments implement penalties or other "sticks" to ensure compliance by industry. And it may require incentives or funding mechanisms, such as feed-in laws or system benefits charges, to allow utilities and their customers to achieve the goals of an RPS.

- **Large, long-term purchase orders.** One of the most important drivers for solar PV growth is long-term stability in the form of consistent and orderly demand. Guaranteed, bulk purchase orders, over a period of 3 to 5 years, provide companies with the confidence they need to invest in new plants and facilities and for installers to train and invest in staffing. In places where governments have helped guarantee large, long-term purchase commitments, such as Japan and Germany, we have seen how the markets respond by building out manufacturing capacity, creating the necessary service and installer infrastructure, and introducing competitive products.

  One manufacturer expressed the sentiments of many in stating that "Bulk purchases are critical at the regional, state, federal level, and within the military." Moreover, federal, state, and local government coordination of procurement specs was mentioned as a possible pathway to increasing orders, as was more cities following in the footsteps of San Francisco in passing initiatives to fund new solar development. No matter the mechanism, the need for coordinated, large, long-term purchase orders by state and local government entities was noted as a key driver to solar's marketplace success.

Conclusion: Policy

While government policy by itself is not enough to accelerate the growth of solar markets, it is essential. Governments have long played a key role in helping to catalyze markets for new technologies. In 2001, for example, just three jurisdictions — Japan, Germany, and the U.S. (with California accounting for the bulk of U.S. PV installations) — represented more than three quarters of the cumulative installed

global PV base — some 839 MW of the nearly 1,000 MW of cumulative PV installed worldwide. The dominance of these three jurisdictions was due in large part to consistent and supportive government policies that have helped to spur demand and gradually bring down prices.

Our research shows clearly that government policies and initiatives can supply critical fuel to the emerging solar flame. In the U.S., this is likely to take shape with state and regional leadership — and, over time, with much-needed federal guidance. But it will take a great deal of cooperation and coordination among government policymakers, industry representatives, and other stakeholders at all levels. We believe such an effort not only would spur the creation of a thriving solar future with limited subsidies before the end of this decade but would also support three equally critical commodities: job creation, economic competitiveness, and increased energy security. A thriving industry may be possible with states and regional leadership – but federal leadership is needed to make the solar industry pivotal.

FINANCE: DESPERATELY SEEKING SIMPLICITY

Finance makes up the third lever of the solar industry triad. Like the others, it presents both opportunities and challenges for rapidly accelerating the growth of PV. Our interviews and research reached three principal conclusions about the world of PV financing:

- **Cost and affordability are the key detriments.** Not surprisingly, the market for PV remains small because potential buyers — consumers, businesses, governments and other end-users — can't afford it. In many cases this is due to a lack of understanding of solar's costs and benefits.

- **Easy financing remains a weak link.** Solar buyers — whether consumers, businesses, or institutions — face a dearth of compelling and affordable financing opportunities. Each purchase seemingly requires customers to reinvent the financial "wheel," using whatever creative strategies they can muster for the purchase to make economic sense.

- **Financiers must reassess the risks of solar.** Large-scale solar projects may deserve better financing terms from lending institutions than fossil fuel power plants receive. Solar panels, unlike power plants, have no moving parts and do not rely on fuels such as natural gas that have unpredictable price swings. They are not beset by regulatory hold-ups or NIMBY ('not in my back yard") protests, the bane new power plant construction projects and major transmission line installations. As such, solar projects have lower risks associated with them, which could make them more reliable investments.

One key problem is that unlike most other energy technologies, solar's costs are almost all upfront capital costs — that is, once the system is installed, the system costs nearly nothing to operate. That makes solar expensive to buy but cheap over the long haul.

At the heart of most solar finance issues is a lack of understanding regarding the true costs of solar and the limited availability of financing options. Lower-cost financing, which could enable more potential buyers to purchase solar, could play the single largest role in breaking solar out of the problem of high prices depressing demand, and low demand keeping prices high.

Key Finance Barriers and Challenges

Reflecting Solar's Full Benefits. Among nearly all industry leaders and experts to whom we spoke, the focus by prospective buyers on the purchase and installation price of solar systems is seen as anything from a distraction to a deal-breaker. The biggest problem is that the true costs and benefits of solar, compared with competing energy sources, are hidden from buyers. "PV's value needs to be calculated as a life-cycle cost," said one interviewee. "PV should be rolled into mortgages. There should be green tags for the environmental value of PV. Developers should role the cost of PV into total construction costs."

One key problem is that unlike most other energy technologies, solar's costs are almost all upfront capital costs — that is, once the system is installed, the system costs nearly nothing to operate. That makes solar expensive to buy but cheap over the long haul. After all, buying solar PV means, in effect, you are purchasing your own "power plant." And while the builders and operators of conventional power plants — run on natural gas, coal, and nuclear power — typically can tap a treasure trove of financing, subsidy, and tax programs that exist to incentivize power plant developers and allow them to amortize and depreciate capital costs over many years, few such programs currently benefit Harry and Harriet Homeowner (or Mom and Pop Business Owner) for developing a solar energy "power plant."

Perhaps ironically, the nature of solar costs should lead to more favorable financing for solar than that which is received by natural gas, coal, or other power plants. When financing large-scale power plants, risk assessment of the project's equipment and future revenue are reflected in several terms of the financing, including the interest rate and the amount of revenue the project must earn in excess of the loan repayment amount (known as the "coverage ratio"). Solar electricity, seen in this light, should be considered to have lower risk on both fronts: solar panels have no moving parts (and, thus, require less maintenance and are less inclined to break down) and the cost of electricity from solar panels is far more predictable than that of natural gas plants (which typically experience considerable price fluctuations). To date, few major financial institutions have considered this lower risk profile of solar — and translated this into more favorable financing terms.

On the consumer side, the problem of high up-front costs could be solved by some good old-fashioned education about the investment potential of solar. For example, if a consumer were to invest $10,000 into a PV system and saved $500 a year in energy

"Utility pricing needs to reflect the real cost of power," said one leading solar company. "If we start to see on-demand and time-of-use metering by the utilities it would really drive the market. Solar can then compete with daytime, peak pricing of 25 cents per kWh."

costs, that represents a 5% annual return on investment — roughly three times what the individual would earn on a 5-year certificate of deposit at current rates. Similar educational engagement with financial institutions also would go a long way to overcome the financing barriers of solar.

But it's not just the upfront costs of solar that put it at an unfair disadvantage. There are other examples of where the true benefits of photovoltaics are not being fully exploited. For example:

- **Time-of-Use Pricing.** In reality, electricity costs vary according to the level of demand and time of day. Under time-of-use pricing (TOU), electricity costs to the end-user reflect that reality. So, for instance, electricity prices to the customer are priced lower — as little as 2¢ to 5¢ per kilowatt-hour — during nights and weekends, when demand drops, and higher — as much as 20¢ to 30¢/kwh — during the day when demand rises. Such a pricing scheme would give PV an edge, since solar energy is produced during daylight hours, when demand, and prices, peak.

  While TOU is available to commercial and industrial customers in many utility districts, few residential consumers have access to TOU pricing, except in a handful of pilot programs. To implement residential TOU would require new electric meters in most homes, capable of recording both the volume of electricity demand and the time of such demand. One study, published in 2002 in the trade journal *Power Economics*, estimated that it would cost approximately $25-30 billion to equip all electricity customers in the U.S. with the infrastructure needed for TOU pricing, though this investment could be recovered in five years if peak electricity demand were to fall 5% nationwide. This seems reasonable: Georgia has seen peak summer demand fall by 5% since Georgia Power implemented real-time pricing for only 1,650 large users.

  "Utility pricing needs to reflect the real cost of power," said one leading solar company. "If we start to see on-demand and time-of-use metering by the utilities it would really drive the market. Solar can then compete with daytime, peak pricing of 25 cents per kWh."

  That's one step. Another is that utility bills need to be understandable so that customers — residential, commercial, and industrial — can get accurate feedback on their energy use, and the opportunities to save money through efficiency, conservation, and alternative energy sources like solar. This could provide a major boon to solar, as customers more readily recognize that the highest prices they pay for electricity are during the day, when solar power is most plentiful. Such feedback also might lead solar buyers to purchase smaller systems designed primarily to shave the "peak" — the highest-price

Of all the marketplace challenges, the financing quagmire may be the most problematic. The current high purchase price of solar is a major barrier for most purchasers, and there are few simple routes most buyers can take to simplify the process or mitigate the costs.

electricity. Doing so could reduce the payback time for solar system purchases, making them more appealing.

But until customers are able to easily understand these pricing signals, such strategies will be impractical for all but the most sophisticated energy buyers.

- **Environmental Costs.** Of course, the full costs of grid-based electricity — at any time of day — aren't covered by ratepayers. Environmental, public health, and social costs aren't reflected in utility bills. According to a study by the Paul Scherrer Institute in collaboration with the Swiss Federal Institute of Technology Zurich: "Expressed in monetary terms as cost per kWh, the damage costs of electricity from fossil fuels are relatively high. They are in the range of 10% to 350% of the production costs, being much smaller for gas than for coal and oil. Particularly large uncertainties apply to the estimates of the damage due to global warming." As one expert told us: "The focus on cost is a distraction. We should be attaching the proper environmental credit to solar — say, 10 cents per kilowatt-hour. Doing so will make solar a very attractive market."

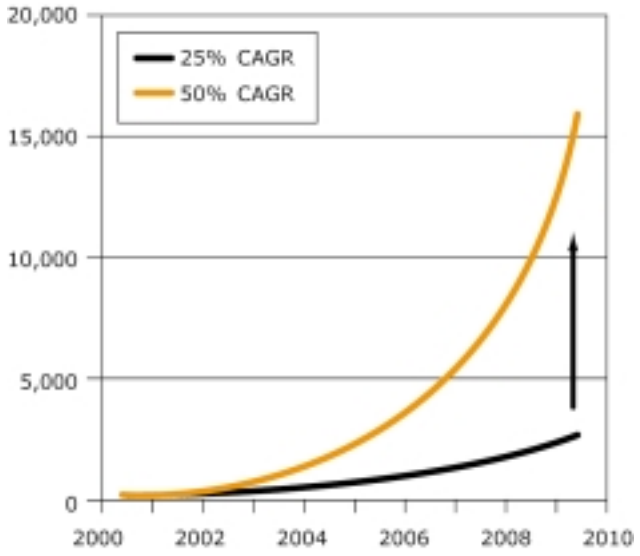
The Financing Quagmire. Of all the marketplace challenges, the financing quagmire may be the most problematic. The current high purchase price of solar is a major barrier for most purchasers, and there are few simple routes most buyers can take to simplify the process or mitigate the costs. The frustration with the lack of reasonable financing alternatives was a constant refrain among the vast majority of those we interviewed. As one expert put it: "Rather than technology breakthroughs, I'm more interested in . . . huge advances in finance structuring."

Among the key issues:

- **The high initial cost of solar systems prohibits many buyers from entering the marketplace.** "People just aren't willing to pay a green premium," said a marketing expert from one large company. Because solar PV systems are often sold (for retrofits, as opposed to new construction) as an add-on appliance, their costs can't easily be rolled into a mortgage payment. That requires customers either to pay a lump-sum cost, assuming they have the "extra" cash to do so; to refinance their property to pay for the solar system; or to finance a solar purchase separately.

  The cost-benefit analysis for solar rarely makes sense for residential buyers, given the typical payback periods of 7 to 15 years (depending on the method of payment and financing terms) — or longer in markets with lower electricity prices and in states lacking rebates and subsidies. Homeowners generally don't invest in improvements with such long payoffs, and business

The Leveraging Power of Financing



According to Michael T. Eckhart of Solar International Management, Inc., and acting chairman of the American Council on Renewable Energy, providing easier access to financing can double the annual growth rate of solar, from 25% to 50%. The accompanying graph compares the compound impact of the two growth rates and demonstrates the leveraging effect of financing on growing the market for solar. At a 25% annual growth rate, worldwide PV installations grow to 2,500 MW a year by 2010; at 50% annual growth, the number grows to 16,000 MW a year. The leveraging effect of solar financing doubles the growth rates, increasing installations more than six-fold.

owners and large companies often balk at solar's tepid return on investment. Said one system integrator of a typical institutional sales experience: "We start with the environmental guys and end up in the CFO's office, and that's where these things get nixed."

- **Third-party financing has been scarce and complex.** Few banks offer solar-financing packages in the manner that they offer prepackaged car loans or tuition loans. There are few other available resources for buyers, whether residential or commercial/industrial, to turn to. Even government buyers are stymied by the large outlays required to install solar. There is an opportunity for financial institutions to greatly simplify the process, offering homeowners and business owners a simple one- or two-page application, with low interest rates comparable to home-equity loans, or to roll solar into an existing mortgage.

- **Government incentive programs can be cumbersome and slow.** In most cases, solar buyers must pay for their systems up-front, then apply for rebates or "buy-downs" from state agencies. Getting repaid can take several months, requiring manufacturers, installers, or the buyers themselves to carry these costs. The slowness can be a burden for all three parties, tying up capital that might otherwise be deployed in the marketplace. This is starting to change. Some states have recently begun paying a portion of the rebate once the equipment is received by the installer, and the balance upon completion of the installation. Such programs need to become more widespread before this problem can be solved.

Key Finance Opportunities and Pathways

All of these challenges create several opportunities for innovation by new or existing players. Among the ideas and suggestions:

Utilities are in the optimum position to help with solar financing because of their existing relationships with consumers and the easy ability to roll monthly solar payments into an existing energy bill. "Nobody pays 30 years of their utility bill upfront," said one industry veteran. "So why should they have to with solar?"

- **Simplified financing.** There are significant opportunities for finance companies or manufacturers to create loan or mortgage-related instruments that make financing of solar easier for residential and small-business customers. The goal is to reduce substantially the upfront costs for installing solar PV, replacing those costs with monthly installments in which a customer's total energy payments — the cost of the PV system plus the monthly utility bill — are comparable to the monthly utility bill prior to the solar installation.

- **New financing instruments.** There are a number of innovative ways to finance solar PV purchases beyond the existing financial networks. For example, in *Bringing Solar to Scale*, we introduced the notion of a revenue-neutral Solar Underwriting Network (SUN), a government-backed entity that could underwrite or guarantee major purchase commitments by business, government, and others, with the proceeds from the resulting sales replenishing any actual expenditures by the fund. Michael T. Eckhart of Solar International Management, Inc., and acting chairman of the American Council for Renewable Energy, has proposed a Solar Bank, a "global capital fund for the financing of the end-use markets for solar energy." (See *www.solarbank.com* for additional information.)

- **New third-party entrants.** Other institutions could step in to offer solar loans at favorable rates, including banks, leasing companies, government agencies, and perhaps nonprofit organizations. Already, some banks have partnered with solar companies — BP Solar with Wells Fargo is one example — to provide easier access to financing for solar system purchases.

- **Low interest rates.** Attractive introductory rates, like many car companies' 2.9% — or even 0.00% — leases, could be a huge boon to solar. As one expert succinctly put it: "Low interest rates will really blow the top off of the market."

- **Utility involvement.** A means of engaging and incentivizing utilities to more aggressively offer solar PV to ratepayers is one of the most direct pathways to growing the market. It was generally agreed among interviewees that utilities are in the optimum position to help with solar financing because of their existing relationships with consumers and the easy ability to roll monthly solar payments into an existing energy bill. "Nobody pays 30 years of their utility bill upfront," said one industry veteran. "So why should they have to with solar?"

- **Marrying efficiency to solar.** A customer's monthly costs can be reduced by integrating energy-efficiency measures along with the solar installation, thereby reducing the customer's overall energy needs. At the residential level, even small energy-efficiency measures can have a huge

There is a great deal of support for new business models, in which solar "utilities" (or energy service companies) sell solar services instead of systems.

impact. Of course, since efficiency typically requires its own upfront investment, this could raise the overall cost of the energy upgrade (efficiency + solar). "There is a need for more PV applications that also enhance the structural aspects of a building," said one interviewee. "The market needs more systems, like PowerLight's offerings, that have extra benefits and building integrated value."

- **Selling watts, not systems.** There is a great deal of support for new business models, in which solar "utilities" (or energy service companies) sell solar services instead of systems. For example, a company might install solar panels on a customer's rooftop (or wherever) and retain ownership of the system, selling the electricity it produced to the customer (and selling excess electricity back into the grid) while the customer paid only for the energy used. In such a system, the "utility" could capture the value of incentives, tax credits, depreciation, and other financial benefits. It may be possible for an entire neighborhood of rooftops to be interconnected to create a kind of residential "solar farm" that could capture cost efficiencies. There are a number of institutional barriers to such arrangements — for example, some jurisdictions place limits on the size of systems that qualify for rebates — but none of these is insurmountable.

  As one interviewee explained: "The Holy Grail is to get a third party to own the system and take the tax credit. I believe it may be possible, but there are huge transaction costs. We need to have an end customer that's willing to take a rate risk, need long-term fixed price contracts, need large enough deals to justify contract costs, and need to find investors who have tax credit appetite."

  For more on the idea of solar utilities, see page 53.

- **Simpler, faster rebates.** There is a significant need to make government rebates for solar purchases simpler and faster, vastly reducing the required paperwork and the time it takes to process it. Arrangements in which rebates go directly to manufacturers or installers, thereby reducing a customer's required cash outlay, also could simplify purchases. However, care should be taken so that such arrangements don't favor the larger, better-financed players and leave smaller ones out of the picture.

- **Tax credits.** State and federal tax credits to offset purchase costs are an important way to stimulate the market and signal to consumers that solar is a desirable technology. Federal tax credits for residential solar existed in the late 1970s but were discontinued; they were proposed in the Bush-Cheney energy plan.

Conclusion: Finance

Financing can drive a new technology — or stop it dead in its tracks. In the case of solar PV, the initial price tag is too high for most buyers, and financing options are few and complex. Getting to scale will require innovation and a concerted effort among a wide range of financial players to make solar more accessible to residential, business, and institutional buyers. In all likelihood, this will require new financial mechanisms — and possibly the entry of new players into the solar financing marketplace.

THREE KEY STRATEGIES

In addition to the three levers, our interviews and research lead us to three cross-cutting strategies for bringing solar to scale:

1 Education

One common frustration is the lack of reliable, comprehensive, and easily accessible information resources about solar — its costs, benefits, and when and how it makes sense. Critical information gaps can be found in all corners of the market, from manufacturers and installers to end users of all stripes and to policy makers.

2 Standardization

The lack of plug-and-play solar systems, whether for residential or commercial/industrial buyers, frustrates buyers and sellers alike. For the former, buying solar requires a dizzying array of options and technical decisions; for the latter, each new installation requires resource-intensive one-off design and installation plans.

3 Market Development and Aggregation

Leveraging the power of bulk purchases — from government agencies, companies, homeowners, and others — to lowering prices through economies of scale is a compelling means of bringing solar to scale. There are a wide range of possible aggregation strategies, each with their own challenges and opportunities.

EDUCATION: THE INFORMATION DEARTH

The true cost of solar versus competing electricity resources is one of many informational needs in the PV arena. Indeed, nearly everyone with whom we spoke bemoaned some aspect of the lack of information about the solar marketplace.

An Information Age paradox exists in the world of solar. On the one hand, there are dozens — perhaps hundreds — of resources on solar energy from governments (national, state, and local), trade associations, nonprofit organizations, utilities, and

for-profit solar companies and consultancies. On the other hand, it is extremely difficult for nearly anyone interested in the industry, from manufacturers and policymakers to building owners and buyers, to find clear, comprehensive, and authoritative information on the topic.

The need for such information looms large among nearly all players with whom we spoke. It's not just buyers seeking product or purchasing information:

- **Manufacturers, investors, and policymakers** have a pressing need for authoritative industry growth projections and current market conditions.
- **Installers and systems aggregators** seek up-to-date information about government policies, programs, and incentives, as well as developments in system financing.
- **Government policymakers and procurement offices** need information about what other agencies are doing, and how they might coordinate purchases or harmonize procurement specifications in a manner that would lower everyone's costs.

Levers and Strategies

Following are examples of how the three key strategies interact with the three key levers.

	EDUCATION	STANDARDIZATION	MARKET DEVELOPMENT AND AGGREGATION
TECHNOLOGY	■ Information on developments and emerging technologies ■ Enhanced awareness of solar benefits ■ Easy-to-use tools to rate solar PV cost projections by region and application ■ Training installers and maintenance personal	■ Improved balance of system components ■ Improved systems integration ■ Simpler, plug-and-play systems ■ Integration of solar into new buildings ■ Standardization of marketing claims of system power output and warranties	■ Improved economies of scale ■ Advances in technology and manufacturing ■ Private-sector bulk purchasing and buyers' clubs ■ Bulk purchases from home builders, universities, others
POLICY	■ Educating regulators and politicians about economic and environmental potential of solar ■ Working with trade groups to develop policies promoting solar ■ Educating policy makers on best practices and what's worked elsewhere	■ National net metering and interconnect laws ■ Time of Use rates ■ Smart meters/invest in grid to make it energy web ■ Feed in laws ■ Building codes for incorporating solar	■ Large, long-term government purchase orders ■ Federal and state renewable portfolio standards with solar carve outs ■ Buy-down programs with declining subsidies ■ Government purchase guarantees
FINANCE	■ Information about the true costs of energy (including the high costs of subsidies for conventional industries) ■ Dissemination of best practices in financing ■ Enhanced consumer awareness of buy-downs and utility programs	■ Simpler financing mechanisms and loan applications ■ Ability to include solar purchases in mortgages ■ Solar Bank/SUN ■ Wide availability of low solar interest rates ■ Marrying efficiency with solar	■ Solar-friendly tax credits and policies ■ Solar futures market ■ Secondary markets ■ Solar utilities/ESPs delivery solar kWh not solar systems

There is a good deal of research and experience on how innovation and technology gets diffused into the mainstream marketplace — as well as research about what motivates consumers to opt for products and services with some environmental or social benefits. The solar marketplace could benefit from this.

- **All industry players** need reliable and trusted information about new products and emerging technologies that might help lower system costs or improve system efficiency or reliability. And there is no repository of best practices for any part of the industry.

Among the strategies that could help fill this informational void:

- **A one-stop information resource.** A comprehensive and well-designed web-based resource with simple and up-to-date information for PV customers could help answer customers' common questions about availability, pricing, and technology. Ideally, such a site could be promoted — or at least linked to — cooperatively by major solar players.

- **Other educational outreach.** Unquestionably, a great deal of education and information dissemination is needed on all fronts, from technical data for manufacturers and installers to a public-relations blitz that helps make solar top of mind for business and residential consumers. "PV is going to have to be 'sold'; people won't come to it on their own," said one interviewee. "The industry will need big players with brand names, low-cost financing, expert delivery and installation. Washing machines are a good example."

- **Linking solar to other successful programs.** Two successful efforts cited as good models — and possible partners — for the solar industry are the federal government's Energy Star program, which provides ratings and marketing support for energy-efficient appliances and buildings; and demand-side management programs by utilities, which provide incentives — such as rebates and free or subsidized insulation or light bulbs — to customers to help them reduce the utility's peak load.

There is no need to reinvent the wheel. There is a good deal of research and experience on how innovation and technology gets diffused into the mainstream marketplace — as well as research about what motivates consumers to opt for products and services with some environmental or social benefits. The solar marketplace could benefit from this, as well as from best practices and success stories of how companies, governments, nonprofits, and others — often working collaboratively — can harness education and communication to build markets.

Our research finds that there is a great deal of interest in how various players might work together to implement bold new marketing initiatives and communications campaigns that could accelerate growth of the solar marketplace. The consensus among our interviewees was that this role would best be filled by a nonprofit organization, trade group, or for-profit consultancy — or, perhaps, some combination of these working collaboratively.

STANDARDIZATION: THE NEED FOR PLUG-AND-PLAY

Today's solar PV systems, like those of any nascent technology, are a patchwork of products, components, and designs, with few industry standards, conventions, or consensus. This is not entirely bad; such diversity helps to spur competition and innovation, as it has with many other technologies, from automobiles to computers to cell phones. It can take decades for an industry to coalesce around a single set of standards.

In the case of solar, the slow pace of coalescence is seen by a majority of experts we interviewed as a major barrier to market development. Among the key issues:

- **Installation is costly and complex,** due in part to the actual time it takes to design and install a system, but also the time and transaction costs of sales and the paperwork involved with securing rebates and financing. This is particularly the case with smaller residential systems, which typically require disproportionately high design time and customized installation relative to the overall price of the system than do larger systems.

  The lack of standardization makes nearly every installation new and different from the ones before it.

  The lack of standardization exacerbates this, making nearly every installation new and different from the ones before it. Solar installers describe the state of affairs as closer to home renovation — which requires extensive space analysis, design time, drawings, permits, and inspections in addition to the actual work — than, say, cable or satellite TV installation — in which a technician applies any of a few proven installation techniques to a handful of preconfigured systems, usually accomplishing the work within a few hours. (Granted, installing solar is far more complex and risky than hooking up cable TV, involving tapping into a home's electrical system — and, ultimately, the local electricity grid — in a way that is safe and reliable. Still, the analogy holds.)

- **System reliability is another concern.** While manufacturers and installers typically guarantee their systems for 20 or 25 years, a large number of solar companies haven't been around that long (though many of the larger players are subsidiaries of established multinationals). As a result, it is unclear what a likely industry shake-out — typical of emerging industries — would do to solar system warranties as today's companies become acquired or, worse, are forced out of business. The reliability issue isn't limited to the systems themselves; it extends to installation — how well a system holds up on a rooftop through two decades' worth of weather. The failure of even a small cluster of solar systems whose manufacturers are no longer around to mitigate the problems could generate a rash of negative news reports about solar, which could have a devastating effect on the PV market. Said one installer: "Reliability [of systems] is a huge issue coming in the next five years that could really hurt the market."

Clearly, the entry of a large, established, brand-name player into the solar installation arena could do a great deal to change the above dynamics. Such a player could reduce all costs — design, purchase, installation, and transaction — through standardized, packaged systems, and economies of scale, and could provide greater assurance that warranties will be honored over the long-term. For now, however, the installation market consists almost entirely of smaller, local outfits, though the entry of BP (initially in California, with additional rollouts over time) as a residential systems installer is one small step in the right direction.

MARKET DEMAND AND AGGREGATION: CAN HIGHER VOLUME CREATE LOWER PRICES?

The history of technology and innovation has clearly shown that when demand rises, prices fall. And as stated earlier, prices of solar PV modules have dropped significantly over the past few decades, though solar systems are still priced out of reach for most buyers.

It would follow, then, that aggregating large purchase orders — perhaps tens or even hundreds of megawatts' worth — of PV modules and systems would cause prices to plummet, perhaps to a level of being cost-competitive with wind energy, nuclear power, and conventional fossil-fuel energy sources. Aggregating customer demand — from governments, businesses, developers, communities, and others — is a potentially powerful way to build the solar market, particularly if such aggregation is designed to gradually bring down prices and serve a range of applications.

Aggregating customer demand is a potentially powerful way to build the solar market, particularly if such aggregation is designed to gradually bring down prices.

Government, in particular, is a likely aggregator of solar system purchases, much as it has with many previous technologies, from transistors to PCs. As we reported in *Bringing Solar to Scale*, the U.S. Department of Defense, needing a lightweight electronic replacement for vacuum tubes for the development of new weapons for the Cold War in the 1950s, made a significant investment in transistors. At the time, transistors cost $20 apiece. Within ten years, they had dropped to 25¢ to 30¢ each. Could government purchases — federal, state, and local — cause a similarly dramatic cost reduction for solar? We believe that they could.

Unfortunately, there is no template for developing aggregation strategies, and there are a variety of pathways that an aggregation program could take. Our survey respondents had a wealth of ideas about the types of programs that the solar industry might find attractive (though, interestingly, many of those we surveyed had not previously thought about aggregation strategies). Among them:

- **Major purchase commitments by federal, state, or regional government purchasing programs.** As stated earlier, the power of governments to create or build markets for desirable technologies has been ably demonstrated in the past. There is a clear role for government in a solar aggregation strategy; using money from bonds or carbon taxes, among other

sources, or even through a revenue-neutral revolving fund; more on this in our description of SHINE, beginning on page 48.

- **Coordinated purchases among municipal and other local government power programs.** Many already have robust solar incentive and procurement programs, among them the San Francisco Public Utilities Commission, the Sacramento Municipal Utility District, the Los Angeles Department of Water & Power, and the New York State Energy Research & Development Authority (NYSERDA).

- **Aggregating orders among home builders.** A number of respondents felt that new home construction was a high-priority target for solar aggregation efforts. Already, some home builders have begun to integrate solar into their new home developments in California. "Homebuilders have a huge role to play. They're the perfect customers for pre-packaged systems," said one interviewee. On the other hand, another stated that, "I don't think homebuilders are going to be a big factor for a while. One of problems in new home industry is getting the appraisers to increase the value of the house, particularly on resale. With average Americans keeping mortgages for 7 years, if you amortize solar over 25 years and the appraiser puts no value on solar system, that's a tough deal. We've got to educate appraisers to add something back in for solar system."

It may be that the best markets for aggregating solar PV purchases aren't traditional grid-based rooftop applications, but niche off-grid, low-power applications commonly used by government and institutional purchasers.

- **Green pricing program affiliations.** There are numerous green pricing programs across various utilities. A number of respondents felt that there might be an opportunity to leverage these programs to promote bulk purchases of solar panels and systems.

- **Utility-based programs.** Utilities could play a key role because, as a few respondents point out, there is a need for an aggregation strategy implemented by an entity that has a direct relationship with the end user — i.e., local energy utilities. Said one respondent: "If you don't have cooperative utilities, you don't have a market." Utilities could benefit by focusing on installations in grid-constricted areas, decreasing the need to build expensive new generation facilities and transmission lines.

- **Web site aggregation channel,** offering authoritative information to end-users on technology options, manufacturers, installers, finance options, etc. Such a channel could connect buyers with installer sources that have access to discounted PV via the network — a web-based Solar Buyer's Club.

- **A solar futures market,** much like that for other commodities, where large buyers can commit to purchase a specific amount of solar energy, with certain specifications, for a certain point in time – and are committed to buy

One fundamental problem is that to create economies of scale, aggregated purchases must be of similar, if not identical, products and systems. Unfortunately, that's often not the case with solar.

if their conditions can be met. Such commitments could be traded within established commodities markets, along with futures for crude oil, winter wheat, copper, and pork bellies.

- **Specialized market niches.** It may be that the best markets for aggregating solar PV purchases aren't traditional grid-based rooftop applications, but niche off-grid, low-power applications commonly used by government and institutional purchasers: highway signs, lighting systems, electric fences, water pumps, augmenting battery banks, or power for remote sheds or out-buildings.

- **Bulk purchases coordinated among schools or universities.** Several individual campuses and university systems have established policies to include a certain portion of solar energy in the construction of new or remodeled buildings. For example, in 2002, students pressed the Los Angeles Community College District Board of Trustees to commit to a 25% renewable energy standard, including 10% onsite generation; in 2003, the Regents of the University of California unanimously voted to install 10 MW of solar across the system's 10 campuses. Creative development directors might reach out to alumni to donate funds for installing solar, ensuring their campuses enjoy low-cost energy for years to come.

- **Promote the growth of renewable portfolio standards.** More than a few respondents felt that RPSs are one of the best tools for creating the right environment for aggregation strategies to thrive. Many pointed to the national commitments to renewables made by governments in Japan and Germany and the significant contributions they made to growing those countries' solar purchases. As stated earlier, however, RPSs benefit solar only when they include "carve-outs" mandating that a specific portion of new renewable energy be designated for solar — and only when the RPSs themselves are enforceable mandates, which include incentives and financing, and not merely window dressing.

Clearly, each of these is worthy of additional research and exploration into their feasibility. And there are likely other ideas and strategies worth considering.

GOING FOR THE GOAL LINE

As the preceding pages clearly show, there is no shortage of good ideas, from the seemingly simple to the decidedly complex, of how to move toward an Accelerated Growth pathway. Many of these ideas can be achieved with existing players, perhaps working in new partnerships of mutual interest. Others will require considerably more political and financial muscle. Next steps will be to prioritize and assess the various ideas, options, and pathways — choosing, in effect, which "levers" to pull, in what combinations, and in what order. The goal will be to select a few key high-leverage inflection points that can move the ball significantly down the field — not merely to plunge forward to gain a yard or two.

What's needed, to continue the football metaphor, is a sustained drive that can put the solar industry much closer to scoring position than has traditionally been the case. In the following pages, we offer a vision for a large-scale national solar effort, as well as suggestions for next steps that can move the ball closer to the goal line.

PART THREE: HYPERGROWTH

The three levers — Technology, Policy, and Finance — and the three cross-cutting strategies — Education, Standardization, and Market Aggregation — provide the basis for our Accelerated Growth pathway, one that could lead to a doubling of solar installations by 2025, compared to what might happen under the business-as-usual, Current Growth pathway.

SHINE calls for two concurrent elements, one promoting the accelerated manufacture, purchase, and installation of solar equipment, the other promoting a new generation of solar energy services.

But what about an even grander vision — a highly ambitious effort based around an audacious, man-on-the-moon-by-the-end-of-the-decade type of goal? A goal that would transform the way industry, politicians, and the public think about solar, and in which a myriad of parties and interests collaborate to create a robust solar future. One that would ensure that solar represents a substantial portion of the energy needs for America and the world. In other words, a "Manhattan Project" for solar.

What would that Hypergrowth pathway look like? And what it would it take to pull it off?

Clearly, there are potentially as many big visions as there are experts. Following is the Solar Catalyst Group's vision, which we've dubbed SHINE — the Solar High-Impact National Energy — Project. The SHINE Project calls for 290 gigawatts of cumulative installed PV in the U.S. by 2025, providing 10% of total U.S. electricity consumption. It involves two concurrent elements, one promoting products — the accelerated manufacture, purchase, and installation of solar equipment — and the other promoting services — a new generation of solar energy utilities.

It is important to emphasize that this vision is only an example of the type of plan that would be needed to take solar beyond being merely cost-effective to the point where it was a critical part of America's infrastructure and was making a genuine contribution to reducing fossil-fuel dependence and global warming gas emissions.

PRODUCTS: MASSIVE INDUSTRY RAMP-UP

To rapidly bring solar to scale requires a simultaneous, coordinated ramping up of both supply and demand. This overcomes the chicken-and-egg problem of high prices depressing demand, which keeps prices high. And a short-term or one-time increase in demand won't work. For manufacturers to scale up their operations or build new plants requires what strategic planners and industry analysts refer to as "sustained, orderly growth" — steadily rising orders over a period of several years. And because it is most cost-effective for both buyers and sellers when things are manufactured in relative proximity to where they are purchased and used, there needs to be ample

incentives to lure Japanese and European — as well as American — solar companies to set up manufacturing facilities on U.S. soil.

But manufacturing and selling mass quantities of solar panels isn't itself enough. To make these panels operational requires that they be assembled into modules, integrated with the inverters and other components that make up the balance of system, installed somewhere, and, ideally, connected to the electricity grid.

The sheer size and scope of SHINE could become a major "carrot" to lure existing companies not yet in the solar field to enter the market.

Therefore, the SHINE Project needs to consider the workforce, technical, and policy requirements for a massive deployment of solar PV systems throughout the United States.

In *Bringing Solar to Scale*, we laid out a roughly similar vision aimed at making California a world-class center of cost-affordable solar manufacturing, made possible by massive public- and private-sector procurement and installation throughout the state. (Copies of *Bringing Solar to Scale* may be downloaded at *www.solarcatalyst.com*.) For SHINE, the major components could include:

- **Large Corporate and Institutional Purchases.** Large buyers — including the federal government, the world's largest buyer of goods and services — will need to play a central role in a massive solar ramp-up. To ensure the sustained orderly market for solar manufacturers, they will need to make major, long-term purchase commitments. The military, state and local governments, real estate developers, home builders, shopping center developers, and others all must be encouraged or persuaded to do their part by making purchase commitments.

- **National Financing Program.** In *Bringing Solar to Scale*, we envisioned a state-run Solar Underwriting Network (SUN), a program that would guarantee the purchase of hundreds of MW of California-manufactured solar modules for little or no recurring cost for the state. The SUN program would incentivize manufacturers to set up shop in California by offering long-term purchase guarantees for "California grown" solar PV. Monies from the sale of these modules to businesses, residences, and government facilities would replenish the fund each year. The fund would help enable residents, businesses and governments in California to install a total of 1,400 MW of grid-connected solar PV within five years. (To put that in context, only 22 MW of grid-connected solar were installed in the entire U.S. in 2002, two-thirds of that in California, according to *Photovoltaic News*.)

  A national version of SUN could be structured in such a way to guarantee a competitive price for long-term sales contracts for manufacturers (for example, starting at $2.80 per watt in Year One and falling to $2 per watt by

Year Four). Such an arrangement would allow manufacturers to lower prices over time as they ramped up their operations.

A national SUN could be set up in any number of ways — as a self-replenishing fund or a purchase guarantee fund, for example. In any case, such a fund would help ensure sustained, orderly growth by enabling both adequate supply and demand, at little or no cost to taxpayers.

- **National Incentive Programs.** The buy-down or rebate programs currently available in California and other states would need to be made national and adequately funded for a sustained period. While this involves a significant government subsidy, it remains small compared to the billions in subsidies given to incentivize fossil-fuel companies. Many state buy-down programs are financed through system benefit charges, or SBCs, a fund created from small tariffs paid each month by utility ratepayers.

SHINE's incentive programs must decrease over time as demand grows and prices fall, so that solar PV system prices don't remain artificially high.

But as stated earlier, many of today's buy-down programs, while helping to grow the solar industry, provide perverse incentives, keeping prices artificially high. SHINE's incentive programs must decrease over time as demand grows and prices fall, so that solar PV system prices don't remain artificially high.

Incentive programs also could be designed to achieve other compelling goals. For example, in the name of national energy security, government agencies might decide to give away solar panels, perhaps funded by ratepayer fees or a small carbon tax, to help stimulate both the supply and demand for solar systems.

- **Manufacture Incentives.** To lure solar manufacturers to build facilities in the United States, and to encourage manufacturers, installers, and systems integrators already in business to scale up, it will be necessary to provide any or all of the incentives typically offered through federal and state economic development offices: deferred or reduced tax burdens, infrastructure assistance, job-creation tax credits, and the like.

A wide range of such programs already exist at the U.S. Commerce Department as well as in most state counterparts. Many of these programs target underserved populations or communities, such as the U.S. Economic Development Administration's Public Works Program, which "empowers distressed communities in economic decline to revitalize, expand, and upgrade their physical infrastructure to attract new industry, encourage business expansion, diversify local economies, and generate or retain long-term, private sector jobs and investment." Other programs are designed to empower states, communities, and other stakeholders in economic redevelopment to work

together in a timely manner to prevent, assess, safely clean up, and sustainably reuse brownfields — former manufacturing sites that have been abandoned and polluted. There are tens of thousands of brownfields waiting to be cleaned and developed. Turning some into solar manufacturing sites, or solar "farms" serving urban neighborhoods, would be highly appropriate.

- **Attracting New Players.** The sheer size and scope of SHINE could become a major "carrot" to lure existing companies not yet in the solar field to enter the market. These could include large plastics companies (since many of the new generation of solar cells are designed for deposition on a plastic substrate), glass companies (a material of choice for the current generation of cells), as well as companies in the electronics, aerospace, automotive, and building sectors. Each boasts technologies and core competencies that could be leveraged in the solar market. A large, integrated company could potentially offer everything from manufacturing to installation to financing. The addition of such large players into the market would help to boost competition, spur innovation, and bring marketing clout to the solar marketplace.

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- **Utility Cooperation.** SHINE would require that electric utilities of all types — large and small, investor-owned or municipally run — play a positive, proactive role. And there are key roles to play for which utilities are uniquely well qualified and positioned. One is investing in developing the myriad pieces of hardware and software needed to enable nationwide time-of-use pricing so that solar systems could sell excess energy to the grid and receive real-time payment or credits. As stated earlier, such a system would benefit solar, since it is most productive during the sunniest hours, when energy demand is at its highest. Another utility role is investing in solar, instead of transmission lines, to relieve grid bottlenecks and congestion.

  Utilities also could play a critical role in providing financing, installation, and billing services for residential, commercial, and industrial buyers of solar systems, leveraging their existing crews, computers, and back-office systems. Customer purchase costs for solar could be included in monthly utility bills and financed in such a way that the added price of the solar system could be largely or completely offset by the energy savings the system provides. Utilities also play a critical role in Pathway Two of SHINE, below.

- **Net Metering and Feed-In Laws.** As stated earlier, laws and regulations that permit owners of solar installations to send excess energy into the grid — and be paid for doing so by the local utility — will need to be expanded, extended, and strengthened. Feed-in laws can spur the development of neighborhood solar "plants" and "farms" — an enormous opportunity for

entrepreneurial cities, counties, and businesses. In Germany, feed-in laws are credited with the dramatic ramp-up of wind energy, now nearly 10% of Germany's electricity generation capacity.

- **Building Code Changes.** An effort should be made to identify places where residential or commercial building codes provide barriers or disincentives to deploy solar PV, or where additional or modified code language could help local jurisdictions approve or mandate more solar-integrated projects. California's Title 24, for example, which regulates the energy efficiency of new residential and nonresidential construction in California, does not currently give builders credit for integrating PV into their designs. Some have proposed that the state of California mandate that solar provide 50% of a new building's energy whenever it makes financial sense (say, a ten-year payback or less). Codes in other states need to be similarly examined and, where appropriate, modified to provide incentives for new solar construction.

To ensure an ample supply of PV installation capacity, we will need to provide financial support for workforce training and other assistance to train installers in disadvantaged and underemployed communities.

- **Workforce Training.** To ensure an ample supply of PV installation capacity, we will need to provide financial support for workforce training and other assistance to train installers in disadvantaged and underemployed communities. Labor unions, community colleges, and other organizations, agencies, and institutions currently working in the field of skills development, vocational education, and workforce training and deployment will need to be deployed in a coordinated program to create the armies of skilled workers needed to install, maintain, and repair solar PV systems. Beyond training may lie the need for a large-scale effort to provide certification and licensing of this burgeoning workforce to ensure its quality and integrity.

- **Public Education.** As stated earlier, there is a great need to educate the public — homeowners, business owners, policymakers, financial institutions, and others — about the benefits of solar. A comprehensive, coordinated national educational campaign — perhaps modeled after successful industry- and government-sponsored public-service campaigns to reduce smoking or drunk driving, or to increase seatbelt use — could stimulate interest in and demand for solar. Additional, more targeted educational efforts would need to provide various constituencies with the information and tools they need to take action. Any such effort should include regular feedback to Americans about how much solar we are deploying and all of the resulting benefits: the number of jobs created, barrels of imported oil avoided, tons of pollutants reduced, etc. Such an effort would require the cooperation and participation of a wide range of organizations, from major media companies to local governments to community groups of all description.

SERVICES: DISTRIBUTED SOLAR UTILITIES

Not everyone wants to own their own solar power facilities — or can afford to do so. Renters, low-income households, space-constrained building owners, and others may be unable — or unwilling — to purchase and install the hardware and systems needed to deploy solar. SHINE provides opportunities for them to join in growing a U.S. solar economy.

In addition to deploying thousands of megawatts of solar equipment, as described above, there is a need to create new solar service companies that can offer customers the benefits of solar without the upfront expense. This portion of the SHINE Project calls for creating solar utilities or service companies in which customers — residential, commercial, industrial, and government — receive solar-generated power from nearby panels, perhaps on their own roofs, that are owned by third parties: solar utilities.

Such a system offers a variety of benefits to both buyer and seller:

This portion of SHINE calls for creating solar utilities or service companies in which customers receive solar-generated power from nearby panels, perhaps on their own roofs, that are owned by third parties: solar utilities.

- The system owners (the solar utilities) handle all aspects of installation, operation, financing, and maintenance. They own the systems, even when installed on a customer's roof.
- The solar utilities receive long-term (say, 10-year) purchase commitments for electricity from the building's occupants. These customers, for their part, receive guaranteed fixed prices, meaning that the rate they pay for electricity will be steady for 10 years, regardless of fluctuations in the overall market.
- The solar utility can sell any excess energy back into the grid at market prices.
- The utility also receives all rebates, incentives, depreciation, and tax benefits. If, as expected, a market develops for trading carbon dioxide and other global-warming gases, the utility also may be able to sell carbon credits or "green tags" on the open market.

In some states, building solar service companies will require changes in buy-down plans, which currently limit the size of refunds a given customer can receive. Solar utilities would need to be able to receive buy-downs or other available incentives for every solar system they install.

This plan also will require that solar utilities can capture the tax benefits associated with solar systems. Nevertheless, these solar services companies could dramatically grow demand for solar systems by offering fixed cost, hassle-free solar on a large scale.

It is important to note that such solar services should not be limited to building rooftops. There are vast untapped "fields" of solar energy to be harvested on parking lots, brownfields, covered reservoirs, and other large, open spaces. Moreover, there may be significant opportunities to deploy solar energy in manufacturing hydrogen for the emerging fleet of fuel cell-powered vehicles, thereby creating another major market for solar panels and services.

Other Key Ingredients

Achieving SHINE's goals will likely require a number of key components. Among them:

There are vast untapped "fields" of solar energy to be harvested on parking lots, brownfields, covered reservoirs, and other large, open spaces.

- SHINE would be bolstered by a national Renewable Portfolio Standard, mandating that a certain percentage of all electricity in the U.S. come from renewable sources by a target date — and that a specific percentage of that total come from solar PV. The solar RPS would include incentives and funding to make it possible – and penalties for failure to reach the targets.
- SHINE would also require that solar PV systems reach some level of standardization, with the ability for turnkey, plug-and-play solar systems to increasingly become the norm.
- To maximize its impact, SHINE will need to integrate energy-efficiency with solar. Ideally, SHINE's army of installers and integrators will learn to profitably bundle energy-efficiency products and services with their solar systems, and ensure that solar-heated or -cooled buildings are adequately insulated.
- Finally, SHINE will need the full participation and innovation of the financial services sector to create financing packages that will enable both systems purchasers and solar utilities a source of affordable capital.

Triple-Bottom-Line Benefits

While the details of a program like SHINE will require a great deal of additional work, even a roughly outlined program reveals the ways a massive ramp-up of solar could provide multiple economic, social, and environmental benefits: jobs creation, workforce development, local economic development, reduced oil dependency, reduced greenhouse gas emissions and other pollutants, reduced stress on the nation's electricity grid, improved public health, and increased national security.

It would also help the U.S. reclaim its former position as the world leader in solar energy, a title currently held by Japan. And it would help unleash the wealth of innovation, creativity, and drive for which American industry is renowned.

CONCLUSION: MOVING FORWARD

The preceding sections indicate the sheer number and scope of the challenges and opportunities involved with bringing solar to scale. As such, there is much work to be done. Following are six recommendations for projects or initiatives that could help focus and further identify key pathways toward ensuring and accelerating our solar future:

Six recommendations for projects or initiatives that could help focus and further identify key pathways toward ensuring and accelerating our solar future.

- **Demand-Side Survey.** A buy-side survey would complement this current report, which focuses more on the supply side. The focus of this new report would be on potential purchasers of solar PV system: governments, business owners, large corporations, utilities, home builders, shopping center developers and operators, REITs and corporate office park managers, and others. The goal would be to learn what it would take to get them to make large-scale, long-term commitments to solar purchases and installations — and, in doing so, to assess the potential market for solar at various price points: $6 per installed watt, $4 per installed watt, etc. To date, no study has effectively looked at the solar PV buy-side, how current and future purchasers of solar PV systems view the present market, and what would likely motivate them to make purchase commitments.

- **Marketing/Messaging Plan.** The goal would be to identify high-impact target audiences — such as politicians and policymakers, real estate developers and builders, general consumers, utilities, business owners, and others — that could drive the growth and development of the PV industry. The study would prioritize target audiences and provide recommended marketing channels, outreach programs, marketing messages for each target audience — outlining calls-to-action and desired outcomes.

- **Utilities Study and Summit.** Electric utilities, both public and private, have a critical role to play in implementing regional and national solar PV initiatives. As stated earlier, utilities can serve as either a barrier or an enabler of the industry's growth plans and strategies. A utilities-based Solar Opportunities Assessment Report — perhaps followed by an industry summit on the topic — would identify key issues and barriers to mass deployment of solar by this sector. Participants would include utilities, regulators, and other key players. The outcome of this Utility Solar Acceleration (U.S.A) Project would be to identify both opportunities and challenges facing the utility industry and to identify pathways for greater utility participation in the growth of the solar PV industry that benefits both ratepayers and utilities.

- **Climate Change Study.** This study would evaluate and quantify the role that solar could play in helping to mitigate climate change. The study, based

on studies with key scientists, policymakers, and others versed in climate-change issues, would highlight the social and environmental issues that solar could help alleviate. The report would help to quantify how much solar would be needed to play a central role ion climate-change mitigation, and over what period.

- **Super Solar Group Initiative.** There may be a need for a major coordinating body to cross all the sectors involved with solar, including equipment manufacturers, marketers, installers, financing organizations, utilities, and regulatory bodies. This organization would be charged with pulling together the various groups and interests to coordinate and orchestrate/lobby for the advancing of common goals: pushing for standards, regulatory changes, technology developments, marketing, education and training, etc. While existing solar industry associations work on many of these issues, their effectiveness is limited because they do not cross all the sectors and players critical to bringing solar to scale. Other energy technologies, from wind to nuclear to coal, have benefited from rallying behind these types of powerful umbrella organizations.

- **"Financing a Solar Future" Project.** There is a need for a research project to identify ways in which breakthroughs in financing could accelerate solar deployment. Such a project could include a survey of existing financial institutions serving the solar market and of the most effective products they offer, and a look at what models from other industries — home mortgages, car loans, home-equity loans, and others – could be emulated or adapted for the solar market. The report would synthesize the most innovative thinking around solar financing, identify the current best practices globally, recommend out-of-the-box ideas, and identify players not yet involved in the solar financing market that could be. The survey would focus on the private sector's role in financing solar purchases but would also consider what steps, if any, federal or state governments could take.

The three pathways presented here — Current Growth, Accelerated Growth, and Hypergrowth — represent critical, strategic choices to be made by the solar industry, political leaders, and citizens alike.

The three pathways presented here — Current Growth, Accelerated Growth, and Hypergrowth — represent critical, strategic choices to be made by the solar industry, political leaders, and citizens alike. They reflect nothing less than Americans' vision of their country and their world in the next quarter-century and beyond. Will our energy future — and all of the economic and quality-of-life impacts that stem from our continued reliance on fossil fuels and nuclear energy — depend, as it has to date, on a seemingly half-hearted effort to move to a more sustainable, renewable-energy future? Or will it reflect a strategic, ambitious, collective effort on the part of industry, government, and consumers to transform our energy future to fully exploit the untapped power of the sun and other renewable energy sources?

We believe, of course, that the latter is not only desirable, but critical to ensuring our economic, environmental, and social health. And that the time is ripe to embrace and implement a collective vision to include solar energy as a pivotal part of our energy future — to move beyond the current pathway by making the rapid and dramatic growth of solar energy an urgent, national priority.

APPENDIX ONE

LESSONS FROM ELSEWHERE: WHAT WE CAN LEARN FROM JAPAN, GERMANY, AND CALIFORNIA

How can markets for solar be accelerated within the U.S.? Answers may be found by taking a closer look at the solar PV policies of Japan, Germany, and California. Combined, these three regions represent more than three quarters of all installed PV systems and well over half of PV module production on the planet. These PV pioneers have a number of common policies, programs, and incentives that provided a jump-start to the use of PV energy on their home turf.

All three jurisdictions had similar motivations: reduce their dependence on nuclear power and fossil fuels as well as their emissions of greenhouse gases. And all three have, to varying degrees, some of the following programs and incentives to increase the use of solar energy at the residential and commercial levels:

- net metering
- rebate and buy-down programs
- feed-in tariffs or performance-based incentives
- low-interest loans
- bulk-purchasing and governmental procurement programs
- tax incentives

Other common influential factors include public awareness and education efforts, intergovernmental cooperation, and funding for research and development.

Following is a summary of select government programs and incentives to promote the use of solar energy in Japan, Germany and California.

Cumulative Installed PV Power in Japan, Germany, and the U.S.
[MW, 1998-2001]

COUNTRY	1998	1999	2000	2001
Japan	133	209	317	451
Germany	54	70	114	195
United States	100	117	139	168
Total	**287**	**396**	**570**	**814**

Japan, with a population of approximately 128 million, accounted for more than half of the three countries' cumulative installations, with 452 MW. Germany, with a population of approximately 82 million, accounted for nearly a quarter with 195 MW. And the United States, whose 280 million inhabitants are more than Japan and Germany combined, accounted for 168 MW.

Japan, Germany, and the U.S. (with California representing the bulk of new U.S. PV installations) currently account for more than three quarters of the cumulative installed global PV base. In 2001, these three regions totaled 814 MW out of the 982 MW of PV installed worldwide.

Sources: International Energy Association Photovoltaic Power Systems Programme and Clean Edge, Inc.

JAPAN: HARNESSING STRONG (BUT DECLINING) SUBSIDIES

Japan, the Land of the Rising Sun, is also the land of rising sun power. Its leadership in solar did not happen without considerable government commitment. Japan's government enacted consistent policies, implemented programs, and invested substantial

funds to create and foster the use of PV. These efforts helped place Japan as the world's leader in solar energy utilization and manufacturing.

Several key programs guided the government's efforts to advance solar. They include:

- significant financial commitment in the form of subsidies and low-interest loans for PV purchases and installation
- the world's leading subsidy program for home systems in the form of the Residential PV System Monitor Program
- solar research programs aimed at lowering solar's per-watt costs by improving the effectiveness and efficiency of solar cells and panels;
- harmonizing inter-agency policies and programs to ensure consistency

New Sunshine Solar energy first made its mark in Japan with the advent of the "New Sunshine" Program in 1992. This program, under the Agency of Industrial Science and Technology, was created to effectively deal with obstacles related to renewable energy, conservation, and environmental protection. These guidelines called for a government-wide effort to introduce new and renewable energy on a national and local level. The guidelines set the equivalent of a national renewable portfolio standard: by the year 2010, new and renewable energy would account for 3% of Japan's total energy supply. The specific target for solar was 400 MW by 2000 and 4,820 MW by 2010.

Japan's leadership in solar did not happen without considerable government commitment. Its government enacted consistent policies, implemented programs, and invested substantial funds to create and foster the use of PV.

70,000 Solar Roof Program. Japan's most effective program to promote and jump-start the use of PV, measured in the amount of megawatts installed to date, is the Residential PV System Monitor Program, also known as the 70,000 Solar Roof Program. In 2001, Japan spent nearly $200 million on this residential solar rooftop program, and more than $800 million over an eight-year period between 1998 and 2001. The program, administered by the National Energy Foundation, promotes grid-connected solar for residential use, owners or developers of multi-housing units, and local governments. Local governments are also able to provide these subsidies to their constituents, providing a second means by which homeowners can obtain subsidies. By the end of 2001, 300 MW of the 452 MW cumulative installed PV power in Japan were from more than 80,000 3-4 kW residential systems installed under this program.

Participants in the program had to meet several criteria. Residential solar had to be grid-tied and use net metering. From 1994 through 1996, the maximum subsidy per system was 50% of total installed costs for systems under 4-5kW (depending on the year). From 1997 through 2001, the subsidy was decreased to 33%. The present subsidy is a flat rate of 120,000 yen (about U.S.$1,000) per kilowatt. The purpose of decreasing the subsidy was to help PV systems become cost effective on their own, rather than remaining subsidy-dependent.

Japan also has feed-in laws that enable residents to sell back excess electricity to the utility at the prevailing rate of 25 yen (about U.S. 22¢) per kWh.

From 1994 to 2001, the budget for the Residential PV System Monitor program had nearly a 12-fold increase in funding. This program was scheduled to end in April 2003, but due to its success will continue through fiscal year 2005. It is estimated that since the inception of the program installed residential system prices in Japan have dropped from nearly $11 watt in 1994 to approximately $6.50 watt today.

GERMANY: INTEREST-FREE LOANS AND PURCHASING COMMITMENTS

Germany has made major commitments over the past thirteen years to advance the use of solar energy. It has the second largest worldwide installed base of solar PV. By far the largest factor in advancing solar energy use in Germany has been the enactment of the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz) or EEG. Though Germany had a program to promote solar prior to the implementation of the EEG, it was not until this law became operational that solar energy use grew significantly.

Three principal programs have guided Germany's leadership in solar:

Germany has made major commitments over the past thirteen years to advance the use of solar energy and has the second largest worldwide installed base of solar PV.

1,000 Roof Program. In 1989, before implementing EEG, the German government started its first solar energy promotion, the 1000 Roofs Program, which ended in 1994. The results of this rebate program were some 2,250 German roofs equipped with PV systems with an average size of 2.6 kW. In 1995, the program had an aggregate installed capacity of 6 MW. The average subsidy covered 70% of the total investment costs for each system.

100,000 Roof Program. In 1999, Germany launched the 100,000 Roof Program, with a goal of installing 350 MW by 2004. The program differs from its predecessor in that it provides "soft" or low-interest loans instead of subsidies. The government allocated about $500 million to the program, making it one of the largest single government solar promotional budgets worldwide to date.

The 100,000 Roof Program initially offered interest-free loans, payable in 10 years, with no payments at all for the first two years. Payback is in eight installments; however, if the system is still in operation by year ten, the final installment of 12.5% is cancelled. Participants in the loan program can also combine this program with any other municipal solar energy incentives, as long as the total assistance is not more than 100% of the total PV costs.

However, the results of this initial loan offer were not very successful. Only half of the planned capacity of 18 MW was installed through the 3,000 new projects that were

approved. One reason given for the slow start and low enrollment was that people were used to the direct subsidies and unwilling to take out a loan. However, after the passage of the EEG, solar energy use got a substantial jump-start.

Erneuerbare-Energien-Gesetz (EEG). In early 2000, the government passed the Renewable Energy Sources Act (EEG), which came into force in April 2000, replacing previous programs. The law's goal is to increase the share of renewable energy production in Germany to 12.5% by 2010.

According to Herman Scheer, a highly regarded German solar energy proponent and president of the nonprofit Eurosolar, the act has two guiding principles to support renewable energy producers. The first is to guarantee solar energy producers access to the energy market; the second is the obligation on the part of utilities to buy a certain amount of solar power generated electricity at a fixed price.

Most significantly, EEG introduced a feed-in tariff or buy-back rate of about U.S.$.52/kWh (nearly four times the price of grid electricity in Germany). In 2002, the tariff began declining by 5% annually to encourage a reduction in costs. Due to the success of this program, the government expects the goal of 350 MW to be completed in 2003 and recently raised the goal to 1000 MW.

CALIFORNIA: THE POWER OF BUY-DOWNS

California is the shining star when it comes to state and municipal policies and programs to promote the use of solar energy in the U.S. No other state has the vast array of programs and incentives to facilitate solar PV systems. California's contribution to the solar industry has allowed the U.S. to claim the number-three spot in worldwide cumulative installed PV capacity.

It was not until 2001 that solar really took off in California. That year, California added more than 6.5 MW of grid-connected PV systems, more than double the previous year's installation rate of 2.4 MW. In 2002, grid-connected systems again more than doubled with the addition of 15.3 MW. Experts attribute this hike in installed grid-connected PV to several factors:

- the 2000-2001 energy crisis, which highlighted the need for reliable alternative power sources
- new incentives such as the 2001 buy-down program from the California Energy Commission;
- the state Public Utilities Commission's Self-Generation incentive;
- the Sacramento Municipal Utility Department incentives;

- the Los Angeles Department of Water and Power renewable energy program.

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Most important by far have been the statewide buy-down programs. These include the California Energy Commission's Emerging Renewables Buy-Down program and the California Public Utility Commission's SELFGEN program. Also key have been the state's extensive R&D investment activities, which have helped innovative companies to grow within the state via the California Energy Commission's Public Interest Energy Research program.

Emerging Renewables Buy-down Program. California's principal buy-down program began in 1998 and required the state's three major investor-owned utilities to collect $540 million from ratepayers over a four-year period to develop renewable energy markets statewide. A $54 million budget was approved for a multi-year rebate program for renewable technologies, including PV, small wind turbines, fuel cells using renewable fuels, and solar thermal electric systems.

Between 1998 and 2000, the program set the maximum buy-down at $3 per watt for PV. The number of PV installations during this period was rather small — a total of 473 systems producing 1.5 MW. In 2001, following the state's electricity crisis, the CEC increased rebates to $4.50 per watt, up to a maximum of 50% of total system costs. High energy prices and the newly increased rebate greatly accelerated the number of applications in 2001 to an average of nearly 300 systems a month. This rebate increase provided a huge incentive for commercial application over the previous rebate of $2.50 per watt. Overall program funding was also increased from $54 million to $100 million, with the vast majority of new funding going to smaller systems.

The growth of PV also could be attributed to several other factors, including a new state solar tax credit, an expansion of net metering size limits, from 10 kW to 1 MW per project, the removal of utility standby charges, and increased marketing by solar companies.

In February 2003, the program's name was changed to the Emerging Renewables Program (ERP) and an additional $118 million was allocated for rebates. ERP is available to renewable generating systems of all sizes, but was designed to favor smaller systems typically used by residential or small commercial and agricultural customers. As specified in the February 2003 ERP Guidebook, PV systems received a $4/watt subsidy, with up to half of the total cost covered for systems up to 30kW. Systems over 30kW are based on a future performance incentive, not developed as of this writing. The rebates decrease by 20 cents per watt every six months, with the first decrease taking place in July 2003, dropping subsidies to $3.80/watt. The CEC has also simplified net metering, reducing the paperwork needed for grid-tied PV systems.

ERP, unlike the California Public Utility Commission's SELFGEN program, has not resulted in the installation of many systems larger than 30kW. Medium and larger system funding ended at the end of 2002.

The results of ERP are impressive: more than 10 MW of installed PV through the first quarter of 2003, with $80.4 million spent by the CEC to cover rebates. The doubling in the number of installed systems from 2001 to 2002 indicates that the increased rebate incentive likely catalyzed a major shift in customer access to solar.

Self Generation Program (SELFGEN). The California Public Utilities Commission SELFGEN program has also contributed significantly to the rise in PV. The rebate program was created in 2001, providing rebates of up to $4.50/watt half of total project costs. The program's target system size is between 30kW and 1.5 MW, making it most useful for commercial installations. Pacific Gas and Electric, Southern California Edison, the Southern California Gas Company, and the San Diego Regional Energy Office (serving San Diego Gas & Electric customers) collectively administer the program throughout their respective service areas. By the end of 2002, 27.4 MW had been installed under the SELFGEN program. The average cost per watt of PV for all four utilities was $8.66. Unlike the ERP program, the SELFGEN does not currently incorporate a declining subsidy.

California also boasts a handful of innovative regional programs, including SMUD's PV Pioneer program, among the first PV program in the U.S.; LADWP's solar buy-down program, which encourages local PV module assembly and manufacturing, was recently bolstered by the Los Angeles Department of Power & Water, which voted to increase its funding; and San Francisco's voter-approved solar bond.

In addition, California offers a range of other incentives to promote PV use, including tax credits, tax deductions, and net metering. Of all the states, California has implemented the most comprehensive set of state- and local-level programs in the nation.

APPENDIX TWO

LESSONS FROM OTHER TECHNOLOGIES: A REVIEW OF TECHNOLOGY DEVELOPMENT AND ADOPTION PATHS

How Four Technologies Achieved Critical Mass

LOW PRICES	CONSUMER VALUE	INFLUENTIAL BACKERS	INFRASTRUCTURE	BETTER THAN EXISTING TECHNOLOGIES
Wind Energy				
Advances in turbine and blade designs and economies of scale drove wind energy below 3c/kWh for some contracts, making wind cost-competitive with fossil fuel generated electricity.	Utilities, under pressure to promote green energy, now have a cost effective source, and an effective marketing tool to burnish their green image.	Tax breaks, RPS, and other incentives encouraged project development and R&D. Enron/GE and FPL brought money, marketing muscle and experience to grow U.S. markets.	Wind can tie into the existing grid. There is still a need to expand transmission networks to areas of greatest wind concentration, which are often far from demand centers.	Wind's environmental benefits are obvious. Design advances mitigate harm to birds and make costs competitive. Still, intermittent nature of wind presents challenges.
Satellite Television				
Fast-growing demand in niche markets and regulatory actions attracted large manufacturers. Technology advances, economies of scale, and low incremental costs for additional customers have led to free equipment.	Improved picture and sound, channel choices and content as well as price-parity with cable TV led to widespread consumer adoption.	Government R&D pioneered satellite industry and set groundwork for commercial uses. Huge companies like GM and News Corp, with deep pockets and marketing expertise now dominate market.	No need to wire an entire neighborhood like with cable. Once a satellite is operational any dish in the country, fixed or mobile (RVs and planes included) can receive the signal.	Digital cable, which provides similar benefits, is only real competition. Compared to free TV and basic cable, satellite service is far superior — hassle-free to buy, install, and use.
Cell Phones				
Cheap microchips and signal processing equipment opened up spectrum capacity and spurred competition from handset manufacturers and service providers. Growth accelerated ten fold in just a few years. Today, free handsets and unlimited calling plans are the norm. Estimates call for 200 million customers in the U.S. by 2006.	The mobility and flexibility that cell phones provide have changed the way people live. Cells phones with advanced features for text messaging, email and internet browsing have led to new applications for business and personal use.	Some of the largest corporations in the U.S. – AT&T, Motorola, Sprint – as well as overseas have built cellular networks and ever-cheaper handsets with greater functionality.	FCC standard setting and rule making allowed for commercialization opportunities and promoted growth. Private companies, with hundreds of millions of private equity, funded construction of cell networks from scratch. Incompatible networks, however, has somewhat limited ease of use.	Cell phones continue to have call quality problems compared to fixed lines. But the flexibility that cell phones provide is unmatched. Almost monthly, networks are upgraded and handsets with increasing numbers of functions enter the market.
Internet				
Originally used by the military and academic researchers, then commercial applications led to huge growth. $19.95 monthly dial up service made widely available in the mid-'90s. Free browsers from Netscape and Microsoft gave people powerful tools to surf the web.	First email, and then online communities and e-commerce, provided the "killer-apps" which brought millions of people to the web.	U.S. Government provided hundreds of millions via DARPAnet and ARPAnet development. Venture capitalists stepped in with Netscape and the explosive growth of other Dot Com investments.	Internet backbone was initially in place via military, government, and educational development of DARPAnet and ARPAnet. The equipment to access the Internet, i.e., desktop and portable computers, were already well entrenched.	Email provided a means to near instantly communicate and share documents in the workplace, and with friends and family around the globe. And the advent of the web revolutionized the way we learn, conduct business, shop, and play.

The development path and adoption rates of various technologies that have reached scale share several key similarities that could provide some useful lessons for growing the solar PV market.

While there are many factors that influence how rapidly a technology develops and is then adopted by consumers, most technologies that succeed generally follow most or all of these five principles:

Mass adoption of solar PV is not a foregone conclusion. It will take a concerted effort by many players, and the coordination of technology, policy, and market drivers, but many aspects of solar PV's technology and adoption path point to a potentially bright future.

- prices must fall;
- consumers need to understand the value of the product;
- the technology should have influential backers;
- an infrastructure needs to be in place; and
- the new technology has to work better than anything it supplants, with a minimum of bugs and hassles.

The table on page 64 shows how four technologies — wind power, cell phones, satellite TV, and the Internet — achieved critical mass. Like PV, these technologies started in niche markets, a classic first step in technology diffusion. As Elizabeth L. Malone of the federal government's Pacific Northwest National Laboratory describes it, niche markets provide "the opportunity to develop new technologies, shaping and correcting them so that they fulfill needs without creating new, insoluble problems. The clear advantages of the new technologies often appear only after their introduction and use in niche markets, that is, after a period of 'learning-by-doing.'"

Lessons for PV

Solar PV has much to learn from technologies that have climbed the development curve and broken through various barriers. Each of the technologies profiled above have moved from nascent markets, initially supported by early government backers and risk-taking entrepreneurs, to major consumer- and business-driven industries with the backing of the world's largest corporations.

In the case of the Internet, it went from a technology used primarily for select military and educational purposes, to one that entered the fabric of people's everyday life. Wind power went from a truly niche market to one in which thousands of MW of new capacity are brought online each year. Cell phones went from the domain of the rich and famous to the streets of Tallahassee, Tokyo, and Trinidad. And satellite television progressed from a select, high-cost offering to a global industry with millions of dishes sprouting up on residences and businesses.

In each of these technologies, one of the biggest drivers was cost. New wind developments now produce energy costing as little as 3¢ per kWh, competitive with fossil-fuel

based energy sources. In many countries, cell phones cost less to buy and operate than traditional land-based telephony options. The Internet is now affordable not only for governments and businesses, but for hundreds of millions of households because of low-cost access that can run just pennies a day. And satellite TV, because of cheap, small receivers with low-cost programming, is now seen by many as a utility more than a luxury.

It took economies of scale to drive down the cost for each of these technologies, but each was able to overcome the "chicken and egg" problem thanks to the multiple factors. Among them:

- Active lobbying of Congress and regulatory bodies by organized industry players and interest groups was critical to the early successes for each technology. Government deregulation, tax incentives and R&D money were just some of the fruits of these coordinated efforts.
- More importantly, the technologies caught on with consumers because of the tangible benefits they offered over the technologies they replaced.
- The marketing and education efforts undertaken by manufacturers highlighted these benefits in a way that was easy for potential buyers to understand and appreciate.

As it is with solar, there was no single factor that led to the widespread adoption of these technologies, but rather a combination of forces and players working in concert.

Solar has many hurdles to overcome to reach this type of mass adoption, but seen through the screen of the five criteria above, it is making progress. For example, solar PV module prices have been trending downwards for the past three decades, moving from $30 per watt in 1975 to less than $4 per watt today. Some manufacturers are now offering bulk purchasers modules for less than $3 per watt. At these prices, solar is starting to reach price-parity for consumers in high-cost utility regions. And the developing world is primed to leapfrog costly grid infrastructure and deploy distributed energy sources such as solar, with the right financial support. Influential solar backers now not only include the governments of Japan, Germany, and some forward-thinking states, but also corporate behemoths like Shell and BP.

Mass adoption of solar PV is not a foregone conclusion. It will take a concerted effort by many players, and the coordination of technology, policy, and market drivers, but many aspects of solar PV's technology and adoption path point to a potentially bright future.

ABOUT THE SOLAR CATALYST GROUP

The Solar Catalyst Group (*www.solarcatalyst.com*) is a nonprofit consortium of business, government, investors, labor, and environmental and community groups and individuals working to catalyze the solar energy portion of a renewable energy future by creating a mass market for solar photovoltaics (PV). Its mission:

> *To harness market forces to dramatically lower the price and accelerate the growth and development of solar energy around the world in a way that aligns energy needs with sound business practices, economic development, environmental protection, and social equity.*

The Solar Catalyst Group is a project of the Co-op America Foundation.

ABOUT CO-OP AMERICA

Co-op America (*www.coopamerica.org*) is the leading national nonprofit provider of consumer, business, and investor tools that put economic power to work for social change. It harnesses the power of consumers and investors though marketplace strategies to address today's most pressing social and environmental issues. In addition to the Solar Catalyst Group, other Co-op America market development initiatives focus on recycled paper, community investing, socially responsible investing, fair-trade coffee and crafts, and development of community-based green businesses.

ABOUT CLEAN EDGE, INC.

Clean Edge, Inc. (*www.cleanedge.com*) is a research and strategy firm that helps companies, investors, policymakers, and nonprofits understand and profit from clean-energy technologies. Founded in 2000, the company is devoted to tracking and analyzing clean-energy market trends and opportunities. Its offerings include customized research and reports; industry databases; distributed generation intelligence services; co-sponsored conferences and events; and strategic marketing services.