HAMILTON CLARK & CO. Fourth Quarter 2004

HAMILTONCLARK QUARTERLY

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A description of the firm and important disclosures appear at the end of this report.

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The Money Chase

Himesh Dhungel, PhD

We continue to track the energy technology sector to assess the level of capital being sought versus how much capital investors have available to invest in these companies. It is not surprising that more capital is being sought than there is available. This simply means that below average business plans get weeded out. The remaining will spar over a limited pool of capital with Darwinian outcomes, the ones who adapt to new financing realities will survive.

Energy Technologies: A Snapshot

We have continued to add new companies to our database, increasing from 660 companies as reported in our last Quarterly to 830 companies today. We have added many new European energy technology companies to our list as a result of our affiliation with a London-based investment bank.

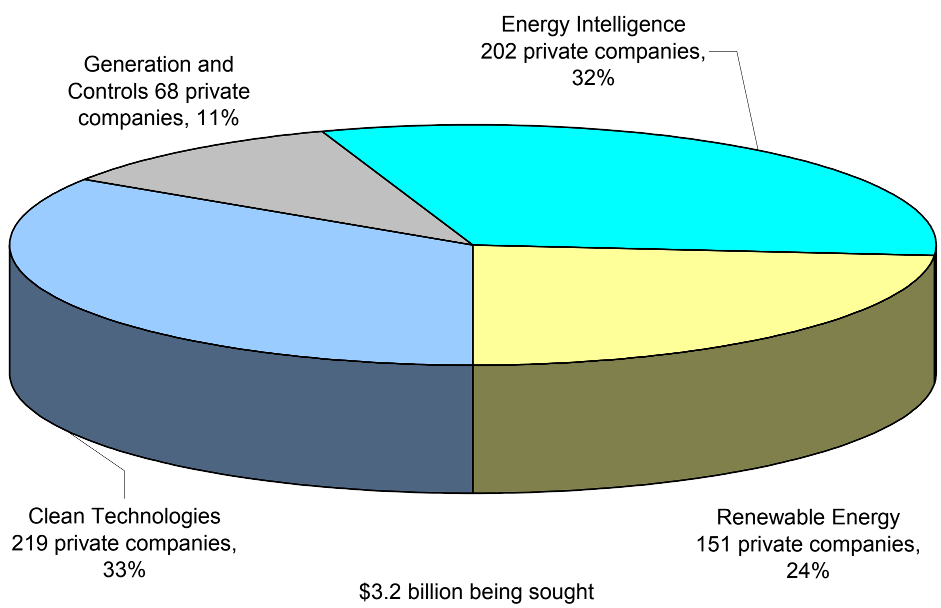
As before, our database is organized around four themes: renewable energy (RE), clean technologies (CT), power generation and controls (DQ) and energy intelligence and optimization (EI).

Technology Category		Examples
Renewable & Sustainable Energy (RE)		
BOG	Biomass/Biogas	Pyrolysis, thermal, landfill gas, coal bed methane, digesters
GEO	Geothermal	Geomagmatic, geothermal
RED	Renewable Energy Project Developer	Project developers
RES	Renewable Energy Services	Systems integrators, service providers
SOL	Solar	Photovoltaics, concentrated PV, solar thermal
WAT	Hydro	Generating equipment, wave energy, tidal energy
WND	Wind	Wind turbine technology
Clean Energy Technologies (CT)		
CFL	Clean Fuels	Methanol, ethanol, clean coal, biodiesel
CPC	Pollution Control/Clean Tech	Emissions reduction, low/zero emission combustion
CTS	Clean Water and Env. Services	Environmental services
EFF	Energy Efficiency	Efficient lights, motors, chips, HVAC, variable speed drive
FCL	Fuel Cells and Related	SOFC, PEM, air mgmt system, stacks
H2G	Hydrogen	H2 generation, storage, transportation
VEH	Clean Vehicles	Hybrids, clean engines
RCY	Recycling	Waste-to-energy
CTO	Other CT	Clean technologies not included elsewhere
Power Generation & Power Quality (DQ)		
DGE	DG Enabling Technologies	Power electronics, controls, embedded software
DGN	Distributed Generation Equipment	Turbines, Stirling, Brayton, internal combustion engines, CHP
DGS	DG Services and Developers	Inside-the-fence, energy service companies
UPS	Uninterruptible Power Systems	Batteries, flywheels, back-up, power conditioning/quality

Energy Intelligence & Optimization (EI)		
B2B	Market-related Software	Energy B2B, marketplaces, trading software, risk mgmt
CRM	Customer Relations/Information	Utility CIS, billing, applications service providers
EEM	Enterprise Energy Management	Building energy mgmt., DSM, reporting/analysis
MET	Metering, Submetering	Meter, submeter technologies
NET	Networks/Telecom	Gateway, wireless device, powerline technology
UAM	Utility Asset Management	Superconductor, T&D tech, asset optimization
EIO	Other EI	Energy intelligence, not included elsewhere

We further segment our database by ownership (private vs. public), region and stage of development (early, mid, and late). Early stage companies are assumed to be pre-beta or early beta with no product for field deployment. Mid-stage companies are those that are post-beta, or early commercial products with limited revenues. All other companies are considered later stage. Some micro cap public companies are mid stage because they still do not have market-ready products.

Segmentation of Private Companies



Source: HamiltonClark research, 2004.

Based on our review of 238 business plans, we validated our thesis that early stage companies, on average, are seeking less capital than later stage companies. Energy is a capital-intensive sector and many late stage companies in the clean technology (CT), renewable energy (RE), and power generation (DQ) segments of this market require product and project financing. Our analysis shows that on average early stage companies are seeking $6 million while late stage are seeking approximately $11 million, with mid stage companies seeking $6.4 million on average.

About 41% of the companies in our database are early stage and 34% are mid-stage. Even though there are almost an equal number of CT and EI companies in the database, more than half of CT companies are early stage compared to only 25% of EI companies. However, it is our observation that early stage CT companies are unlikely to receive traditional venture capital financing because of their capital-intensive nature and lack of liquidity opportunities.

We estimate that approximately 60% of the companies in our database or 495 companies are seeking capital, including micro cap public companies (as evidenced by the number of PIPE transactions taking place in the market). Almost 60% of those seeking capital are early stage, 35% are mid stage and the rest are later stage companies looking for product or project financing.

Will all these companies close deals? We believe that only about 15% to 20% of those seeking capital will eventually get financed. The others will have to try their luck with friends and family or sell to or merge with others.

Deal Terms

John J. McKenna

Recent financings for energy tech companies have displayed some perceptible trends that CEOs and CFOs should understand. The key issue is the old bugaboo of private equity – internal rate of return. It's as visible as the nose on your face. What this means to CEOs and CFOs in this sector is that:

- *Investment capital is scarce*
- *Themes are important because early exits really impact IRR*
- *Deals need to be priced at low valuations*

Looking in the Rear View Mirror – Where Have We Been?

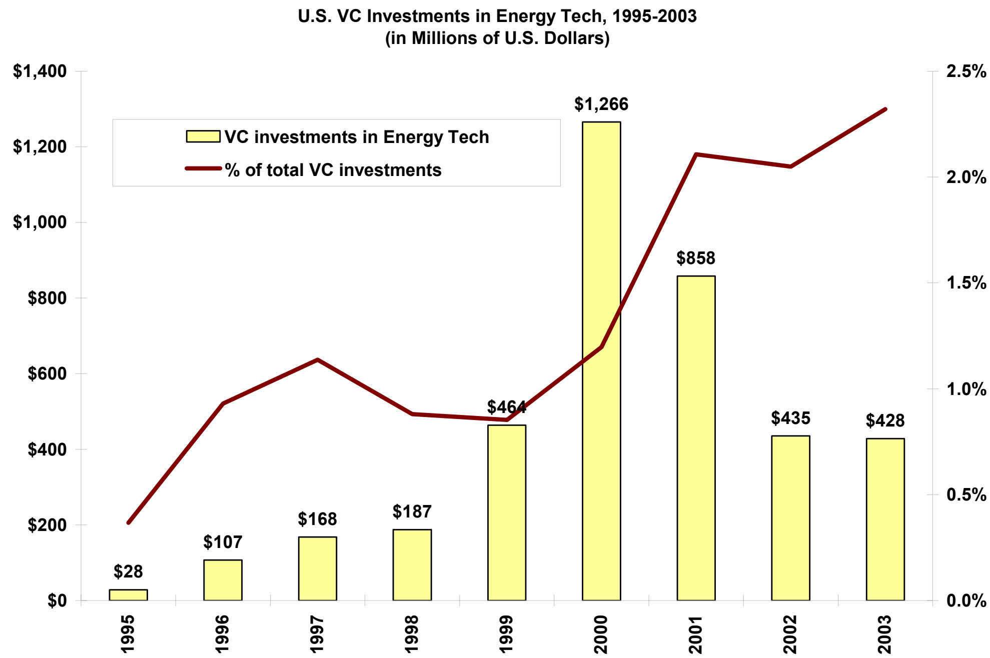
Let's look at what has occurred in the last 12 months.

Supply of and Demand for Capital in Energy Tech

Our firm is currently tracking 830 energy tech companies in Europe and North America, with about 500 companies currently attempting to raise capital. Of the 238 company descriptions we have reviewed, the average amount of financing being sought by each company is about $6 million. More financing (including product finance and project finance) is being sought for later stage companies and less for early-stage companies. Although not scientifically determined, we believe that about $3.2 billion is currently being sought by companies in the energy tech sector.

On the supply side, in our last assignment we identified about 100 private equity investors and about 50 strategic investors that claim to be looking for investments in the sector. Within our proprietary database of well known energy tech investors we currently count about $550 million of un-invested capital. This includes $100 million recently closed by Prospect Street Energy in the form of a publicly-traded business development corporation. Non-traditional energy tech investors are hard to gauge but our belief is that about $250 million is available from first time energy tech investors. Therefore, there appears to be about $800 million available to finance about $3.2 billion of deal flow.

Most experts believe that up to $500 million will be invested during the next 12 months. This is better than 2002 and 2003 but well below 2000 and 2001 levels as highlighted on the following chart.



Source: PriceWaterhouseCoopers MoneyTree and Nth Power.

Who's Attracting Capital?

Over the past 12 months we have seen a movement away from traditional energy efficiency and renewable energy investments, into more high tech investments in the sector. However, for closings and negotiated term sheets, valuations have either been at or below par value of prior money invested with virtually no financing at or above 2000 and 2001 valuations. A strategy used by some private equity investors is to "wait-out" the company until a negotiated transaction is tantamount to re-staring the company as if it had been sold for little or no value. See General Electric's purchase of Astropower. It is a good set of documents that show how a "re-start" can be avoided by shopping the company prior to a transaction.

Among all sectors of energy tech, a clear winner is anything dealing with materials. This covers nano materials, particle fuel cells, wireless "dust" networks and energy storage. Materials-based business plans often emphasize a common issue: small, efficient and focused on negawatts.

Representative deals and their $US equivalent raised in the last 12 months include:

- **Ocean Power Technologies** $45 million AIM offering for wave technology
- **Biofuels** $27 million AIM offering for biodiesel
- **STM Power** $24 million for Stirling engines
- **Solar Integrated Technologies** $22 million AIM offering for thin film PV
- **Evergreen Solar** $20 PIPE offering for PV
- **Polyfuel** $18 million for fuel cells
- **Konarka** $18 million for nano PV
- **ITM Power** $18 million AIM offering for fuel cells
- **Ocean Power Delivery** $14 million for wave technology
- **Millennium Cell** $10 million PIPE offering for hydrogen

- **Dust** $7 million for mesh networks
- **Encorp** $7 million for power electronics
- **Lynntech Industries**, now **Fideris**, $6 million for fuel cells
- **Clean Air Power** $6 million for combustion technology
- **Energy Conversion Devices** $6 million PIPE for fuel cells and PV
- **ElectroEnergy** $5 million PIPE for batteries
- **Azure Dynamics** $3 million AIM offering for hybrids
- **Windlogics** $3 million for wind
- **Nanostellar** $3 million for nano catalyst
- **Southwest Wind** $2 million for wind turbines
- **Enerpulse** $2 million for combustion technology

Editor's note: AIM refers to the Alternate Investment Market which is part of the London Stock Exchange. HamiltonClark has a partnering agreement with a U.K. broker to co-manage AIM offerings. PIPE refers to a Private Investment in Public Equity which essentially is a private placement for a publicly traded company. The author is a shareholder of STM Power, Inc.

Valuations

We are currently tracking three markets:
U.S. Private Equity. The range for pre-revenue companies is still single digit valuations at or about par from the last round financing, down to a valuation close to outstanding payables for restarts. Post revenue companies are valued today at about 2 to 3 times revenues.

NASDAQ. Average multiple of revenues for 30 micro-cap (under $250 million of market cap) and 25 small cap ($250 to $1 billion market cap) companies we track is about 5.1 times revenue, but with a wide range.

London AIM market. Two post revenue deals are trading at an average multiple of about 15 times revenues. Three pre revenue deals are currently trading at an average valuation of £31 million ($57 million). Most investors feel that valuations will come down on these issues, closer to NASDAQ multiples.

The key valuation metric has become the "value proposition" to the end use customer, measured by purchase orders and customer feedback during investor due diligence interviews.

Look At the Instrument Panel – Where Are We today?

Understanding the dynamics of the private equity market might shed some light on why terms are so difficult and what drives investors to certain business plans. Pressure to generate IRR is way above the comfort zone.

How Private Equity Works

This space is not adequate to fully explain the complex world of private equity. But there are four key issues that influence how a financing is reviewed by investors. We believe that it is helpful for CEOs and CFOs to understand these four rules of private equity.

- **Managers of VC funds only get about 20% of the "net gains" above a target annual return.** The general partners of a typical investment fund need to have some early exits (in years two and three) at IRRs in excess of their targets in order to make up for slower deals and exits that are below the target IRR. This is all a function of the arithmetic of the fund. Investors (limited partners in an investment fund) generally agree to give the manager (the general partner in an investment fund) a “carried interest” equal to 20% of the “net gains” of the fund after the limited partners have received an annual return of about 8%. “Net gains” means that money is returned annually to the limited partners before it is returned to the general partner and returns are computed on the total amount of the funds invested, not on a deal-by-deal basis. If exits do not occur until year five or six, the 8% adds up. If the portfolio is not trendy then companies cannot exit in the early years. Whenever exits do occur, distributions are paid 100% to the limited partners and then to the general partner. In some cases, the general partner might struggle to ever get to payout if exits are delayed.

- **Exits generate a liquidation preference for the private equity investor.** We are amazed at how few CEOs actually understand this calculation until they are looking at an exit event. Had they understood it, they often admit that they may have managed the company differently. This clause means that at an exit event, the private equity investors (i) get their original investment back (or in some cases a multiple of their investment), usually with the accrued dividend from the date of the investment, plus (ii) conversion to common stock as if they had been a common shareholder all along. This has a tremendous impact on the investor’s IRR for deals that perform well but are not a grand slam.

- **All new financings need approval of the private equity investor.** This is for obvious reasons to protect the investor from dilution, even with anti-dilution protection.

- **The private equity investor is almost always attempting to raise a new fund.** Replenishing investment capital is a constant challenge for general partners. Consequently, long investment horizons, project financed business plans with utility-based returns and undisciplined R&D programs are not popular.

Look Over the Horizon – Where Are We Headed?

Ever since 2000, when a number of companies went public (Capstone, Plug, Proton, Hydrogenics, Evergreen, Beacon), IPOs have been rare in the U.S. CEOs and CFOs who are seeking financing from private equity investors should understand that lack of portfolio exits hurt the industry’s appeal to new investors. Some helpful hints:

- **Funds that have experienced losses or write-downs must be especially aggressive on valuations for new investments.** Back to the IRR calculation. If a fund has a loss or write-down in the portfolio, it needs a real winner to get back to par. Down-round financings are often an indication of this situation. See our Second Quarter 2004 Report (available on our website at www.hamiltonclark.com) for details concerning down round financings.

- **Financings that are priced way in the money have a great advantage.** The best advice to CEOs and CFOs in this market is to understand the dynamics of valuation and price their deals at values that appeal to investors. The market will improve and future deals can be aggressively priced. But not now.

- **Your exit strategy must be an important part of your financing plan.** Private equity investors in today’s difficult market are attracted to CEOs and CFOs who understand the need for an early exit. Therefore, plans need to be intense, sell what’s available today, and have what a recent conference attendee called “a passion for adequacy”, meaning that an average product that generates revenue today is far better than an excellent product that never gets to market, Re-read The New, New Thing. Other suggestions include drafting a Private Placement Memorandum that can be easily converted to a red herring, AIM Pathfinder or M&A proxy. Use a well known accountant and get the financials audited. Hire a lawyer who is well versed in securities transactions and can help you clean up conflicts and poor documentation.

- **Selling the Company might be a better solution than a financing.** The pressure for build-ups of successful companies in order to get to market may mean that merging the company is a better plan for wealth creation. Partner up with a company that complements your technology so you can both get financed, be able to build the combined company and focus on the customer.

- **Look at the AIM market in London.** HamiltonClark advises companies with respect to AIM offerings.

Conclusion

There are a number of very professional investors in the energy technology sector. Unfortunately, there have not been many home runs recently and portfolios are stressed. We believe that there is about $3.2 billion of financing being sought from a pool of about $800 million of investment capital. CEOs and CFOs can differentiate their plans by cutting their valuations, managing to a three year exit and having their plans packaged as if they were looking for a buy-out or an IPO.

There are better times ahead, but not soon.

Managing Your Way to the Next Financing

Ross F. Crawford

How companies define operating issues can determine the success of the next financing. In managing five early-stage technology companies employing from 10 to 120 people, I have repeatedly encountered the same operating issues. There are many “old saws” that can be useful for CEOs and CFOs to consider as they embark on their next financing. This article offers some “how to” advice for senior managers.

Burn Rate - Getting Beyond Payroll

Attracting new capital to an existing early-stage enterprise starts with a realistic grasp of the importance of positive cash flow. The faster a company can establish the predictability of its cash cycle, the better able it will be to communicate its value proposition during investor due diligence.

Getting beyond the payroll cycle means more than simply generating revenue and collecting receivables. These actions are all critical elements to success, but none of them happens by accident. And while growing revenue or raising new capital are important, turning receivables to cash is vital.

Are there things that can be done now that can really impact cash flow? It’s easy to overlook obvious opportunities for savings, so here are a few simple suggestions that have worked for me in the past:

- Make sure you have sophisticated internal control procedures and tools to manage billing, contract management, budgeting, and project management.
- Involve the employees by reviewing the suggestion box or start one if you suspect that employees are not receiving adequate feedback from within the organization.
- Review price lists and the bid process as well as payment terms for sales commissions to compensate upon receipt of payment.
- Set and enforce tighter project deadlines, rethink work rules or policies that might be impeding productivity improvements. Put firm end-dates on any initiative.
- Kill pet projects that may demonstrate technology but do not produce revenue.

- Align pay and performance, not just among sales employees, but among vendors, contractors and advisors.

- Take a critical look at the "company culture".

In short, are costs and value properly aligned? Have you discussed pay for performance among vendors, contractors and advisors? Is value being received from each class of expenditure? Are you recognizing the importance of involving the employees in a constructive fashion? When the company's future is on the line, good employees tend to be ruthless in finding inefficiency and waste.

It's Really About Leadership

Managing within projected cash flow is the leader's most critical task. Investors size up management by evaluating how they perform against their own goals. Have they planned for revenue while none has appeared? Is there revenue but working capital has consumed all the cash?

Because successful leadership in an early-stage business is a very personal matter, demonstrating that skill to educated outsiders for the purpose of raising capital is a challenge. Here are some things that have worked for me:

- Know your product and how and where it should fit in the marketplace. Avoid re-shaping it to find a market.

- Know what your competition is doing and anticipate how it might impede your effort to reach a market.

- Understand current market pricing and the price erosion that your product will encounter.

- Talk to anyone and everyone knowledgeable in your sector. Identify candidates in similar businesses that are further along than you are, and listen to them. By becoming known and respected in your industry, your circle of advisors will broaden and may lead you to new investors.

- Your energy level will set the tone within your company, as will your confidence in the strategy the business is pursuing. Employees may recognize weakness in a plan more quickly than the planner.

- Constantly retest your plan's assumptions against the realities of the market and the ability of your products to generate cash flow.

- Build a team of directors and advisors who want to help you avoid errors. Work at listening to them. Access to advice from a team of experienced businessmen is a great asset for any new business.

Getting Customers On Board

Probably the most important ingredient in a successful financing is to make sure that customers will buy your products. In Crossing the Chasm, Geoffrey Moore's primer on how to sell technology products to people who don't want them, he quotes a Zen proverb.

First there is a mountain,
Then there is no mountain,
Then there is.

He then translates this into the CEO's challenge.

First there is a market,
Then there is no market.
Then there is.

During investor due diligence, customer support can be identified in two ways: composition of the sales funnel, and client endorsements. Here are some helpful hints about organizing the process so that investors obtain a true picture of your relationship with customers.

- Identify key local prospects that might benefit from your product and work with them during the development phase. This might involve development contracts in exchange for cash, early pricing advantages or enthusiastic early adopters who want to be a beta site.
- Beta sites should be near the Company for the simple reason that you can monitor the performance of your product much more closely. Furthermore, investors do not like long road trips.
- Get the product completed on time. Technology-based companies are routinely inattentive to basic product testing or documentation. This can be deadly for early stage companies if customer are not satisfied and returns occur.
- Schedule adequate time for beta testing. You know your product too well to provide an independent test environment. Beta customers will help you communicate your product's value proposition to the market, if you listen.
- Understand who will use the product. Be sure to clearly differentiate the benefits of your offering from those of established competitors, and present your value proposition in a way that the customer will understand it.
- Develop a contingency plan for getting to the market. Your urgency and that of your distributors may not always be aligned.

Documenting the Plan

All of the foregoing needs to be encapsulated in a suite of documents so that the company's value proposition is communicated succinctly. Although most companies focus on business plans and flashy presentations, a successful financing requires a well-documented financing plan.

Having written financing plans for many early-stage companies seeking financing, I offer only one suggestion. Don't do it yourself. Here's why:

- Managers and senior staff are biased. When it's your baby it's harder to see the warts and blemishes or to know where an outsider might perceive value.
- Advisors and consultants know more about what investors are looking for. The CEO and CFO are working day and night to bring their vision to fruition, while advisors are working just as hard to match investments with investors.

- Business plans are useless when the discussion turns to deal terms and the relationship among classes of investors. Without a thoughtful plan, investors may propose terms that are a “worse case” scenario.

- Offering documents that include full disclosure are the only protection for misunderstandings and potential liability for officers and directors under the securities laws.

- The Private Placement Memorandum, Financial Projections, investor flip book and the due diligence files all need to be seamlessly integrated. When seeking capital professionally, the investor expects to receive a complete package for consideration rather than a business plan or PowerPoint presentation.

Conclusion

Having experienced many pitfalls on the road to financing and selling early-stage companies, I am a firm believer in four cardinal rules:

1. Have your cash flow managed so that you can wait out the procrastinating investor.

2. Make sure that management and employees have bought into the plan.

3. Customer endorsements and a good order-book are critical. In investor terminology it’s called “visibility of revenues”.

4. Forget re-writing your old business plan. Get help from an advisor with proven results in reaching the private equity market.

Editors Note: Ross Crawford is a Managing Director of HamiltonClark and is resident in the Houston office. In addition to being a General Securities Principal and having spent 25 years in corporate banking, he has held senior positions at a number of early-stage companies including Identification International, HydroTech Systems, Ruska Instrument Corp, C2C Fiber and Vuico, LLC.

Technology Matters - Photovoltaics

Himesh Dhungel, PhD

With the price of crude oil hovering above $50 a barrel, energy experts and public officials are debating how to deal with the potential economic implications of sustained and volatile energy prices. Discussions have ranged from opening up federal lands for exploration and development of oil and gas to the promotion of renewable energy sources and ultimately the creation of a hydrogen-enabled economy. Pinched by higher energy costs and efforts to improve the environment, consumers are already responding by purchasing alternative energy products and services such as hybrid vehicles, solar photovoltaics (PV), solar water heaters and energy from wind power. With the financial backing of venture and institutional investors, entrepreneurs are starting to develop next generation alternative energy products and services. In this article, we take a closer look at the PV industry landscape and analyze the market drivers, different technologies, business models and more importantly, the economics of PV.

Background. Industry experts estimate that PV installations in the U.S. grew by over 30% in 2003 to approximately 40 megawatts (MW). Globally, almost 575 MW of new solar PV capacity was added in 2003, representing close to 35% growth over 2002 level. (Note that the amount of new PV added pales in comparison to approximately 1,700 MW of new wind capacity added in the U.S.) What is fueling PV's growth and is it sustainable? Is solar PV a mass market-ready technology? If not, what is hindering the wider adoption of this technology and can the market address this without state or federal incentives?

Industry Drivers. We believe that the U.S. PV industry has benefited from three developments in the electric industry: (a) the creation of state renewable portfolio standards; (b) incentives financed from public benefit funds; and (c) utility net metering rules. OEMs, developers and installers have responded well to these developments by increasing manufacturing capacities and offering more products and services.

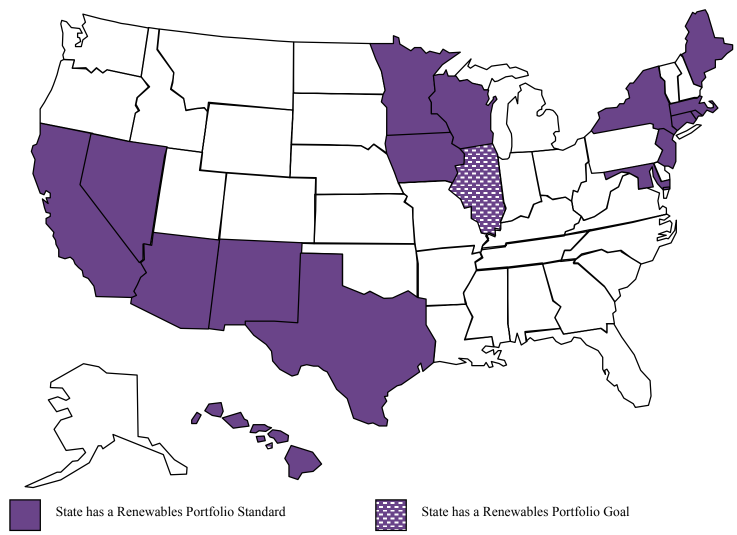
One significant driver of PV growth has been the public benefit funds created to promote research and development, low income energy assistance, energy efficiency and renewable energy use. States have an estimated $2 billion of public benefit funds, of which approximately $300 million are targeted for renewable energy programs. At $135 million, California's renewable energy program is the largest among all state renewable energy incentive programs.

The reason for increased level of interest in PV becomes clear when we look at some of the available incentives. For example, California's SELFGEN incentive program involves four levels of rebates where Level 1 incentives include photovoltaic, fuel cells operating on renewable fuel, and wind turbine technologies, and projects receive the lesser of $4.50/watt or 50% of project cost for project sizes of 30 kW to 1.5 MW. For a 100 kW installation at a fully installed cost of $7 per peak Watt ($7/Wp), the incentives can be as much as $350,000. Such incentives are more generous in Europe. For example in Germany, low interest loans combined with PV electricity buy-back rate of approximately $0.45 per kWh (declining by 5%

annually from 2002) have increased solar PV capacity from approximately 72 MWp in 1999 to about 425 MW in 2003.

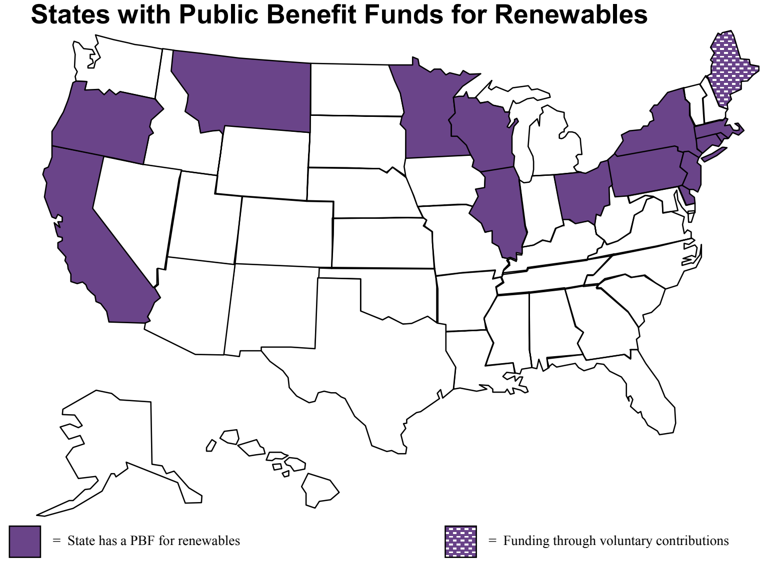
Without the incentives, the PV industry is unlikely to maintain today's growth trajectory, particularly in grid-tied markets because alternatives are much cheaper. Off-grid markets are likely to continue their current growth particularly in developing countries because in these countries PV competes with expensive alternatives such as kerosene and diesel.

Renewable Portfolio Standards



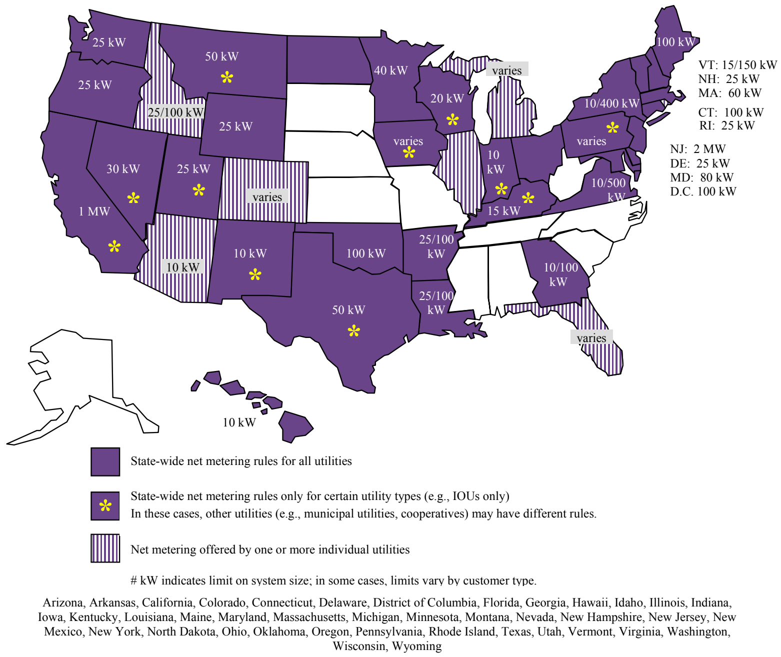
Arizona, California, Connecticut, Hawaii, Illinois, Iowa, Maine, Maryland, Massachusetts, Minnesota, Nevada, New Jersey, New Mexico, New York, Rhode Island, Texas, Wisconsin

States with Public Benefit Funds for Renewables



California, Connecticut, Delaware, Illinois, Maine, Massachusetts, Minnesota, Montana, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Wisconsin

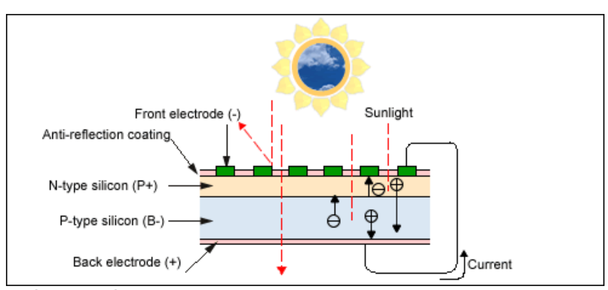
Net Metering Rules



Source: U.S. Department of Energy, Database of State Incentives for Renewable Energy

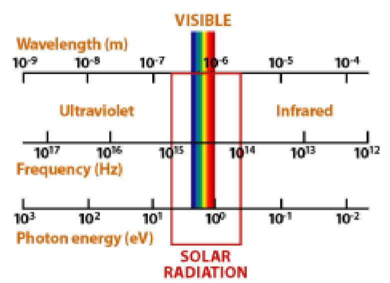
The growth induced by subsidies and incentives have allowed economies of scale to be exploited while allowing entrepreneurs to develop more cost effective technologies. However, incentive-financed growth is unsustainable. For long term success, PV will have to succeed on its economic merit not on subsidies. Although higher PV production in the last decade has helped reduce cost, the industry will have to rely on design-driven cost reduction and efficiency improvements to deliver long term value to consumers. Market developments suggest that this is possible as a result of cross-over technologies from the semiconductor and material science industries (electronic chips, ink-jet, and nano-science).

Technology. Solar cells or PV cells are light absorbing semiconductor materials that convert solar energy into electrical energy (see picture below). The most common semiconductor materials are silicon (Si) and gallium arsenide (GaAs), which are widely used in the microelectronics industry.



Source: Solar Energy Industries Association

Packets of light, or photons, contain energy. When light shines on a semiconductor material, such as crystalline silicon, electrons from the semiconductor material's atoms may be freed. These freed up electrons, when connected to an electrical circuit, produce electricity. Whether an electron gets dislodged from its atom depends on the level of energy, called "bandgap energy" of the incident photon. To free an electron, the energy of the incident photon must be equal to or greater than the bandgap energy. The level of the bandgap energy of photons depends on the wavelength (or frequency) of the light. The spectrum of sunlight ranges from low bandgap energy (0.5 electron-volts or eV) infrared to high bandgap energy (2.9 eV) ultraviolet rays. (An electron-volt is equal to the energy gained by an electron when it passes through a potential of 1 volt in a vacuum.) The illustration below shows the spectrum of sunlight from infrared on the right to ultraviolet on the left, with visible light in the middle.



Source: U.S. Department of Energy

PV cells cannot respond to the entire spectrum of sunlight and therefore all sunlight is not useful sunlight. Photons with less energy than the semiconductor material's bandgap energy are not absorbed, while photons with more energy are reflected or converted into heat. Scientists have estimated that 55% of the energy from original sunlight is wasted. To overcome these limitations, the PV industry has attempted to find materials and manufacturing techniques that help reduce the cost of PV cells by (a) increasing cell efficiency; (b) reducing manufacturing cost; or (c) both.

Solar cell materials. To understand the evolution of PV, it is important to understand the microelectronics industry. Semiconductor materials used in the microelectronics industry are of prime-grade. Consequently, any off-specification material is available for other use or wasted. The PV industry has historically taken such off-spec material rejected by the semiconductor industry. However, with the rapid growth of the PV industry, scrap silicon is not as abundant, and more expensive prime-grade silicon is required. Growing and casting prime-grade crystal is expensive because of its energy-intensive process where silicon is melted at very high temperatures (1600°C). Economics has led the industry to improve cell efficiency, reduce material use, and develop low-cost manufacturing techniques. Cell efficiency can be improved by selecting semiconductor materials with energy gaps (bandgap energy) that closely match the solar spectrum and by optimizing optical, electrical and structural properties of these materials.

Solar cells can be made from a variety of materials such as:

- Single-crystalline thin film such as gallium arsenide (GaAs) and gallium indium phosphide ($GaInP_2$)
- Silicon (Si) including single-crystalline Si, multicrystalline Si, and amorphous Si
- Polycrystalline thin films such as copper indium gallium diselenide (CIGS) and cadmium telluride (CdTe)
- Dye-sensitized nanostructure titanium oxide (TiO_2)

Investors looking to invest in the PV sector need to understand the pros and cons of each type of technology. As our analysis below shows, just because a particular technology exhibits tremendous technical merit does not mean that technology will necessarily succeed. There are perceived risks associated with certain technologies, while others may not be cost-reducible even at reasonable volumes. Investment decisions need to balance technical merit versus market acceptability of technologies.

GaAs and GaInP$_2$. PV cells based on these materials exhibit the highest efficiency, approaching 30%. Cells made of these materials have also shown superior radiation resistance. Because of the radiation property and generally higher cost of manufacturing, these PV cells are often used in concentrator systems and space power systems.

Even though gallium-based cells have the promise of very high cell efficiencies, they suffer from two critical issues - economics and perceived health risks of the feedstock used in production.

Crystalline silicon (Si). Silicon is still the most common material used in solar PV. Silicon can come in various forms including single-crystalline (sc-Si), multicrystalline (mc-Si), polycrystalline (pc-Si), or amorphous (a-Si). In sc-Si, the atoms making up the crystal are repeated in a very regular, orderly manner from layer to layer. In contrast, with non-single crystal silicon, the orderly arrangement is disrupted moving from one crystal to another.

The oldest and the most expensive use of silicon for PV manufacturing was to create silicon in a single-crystal state, the same method used in the microelectronics industry. High-purity semiconductor-grade silicon is melted at very high temperatures and through extensive metallurgical processes, large cylindrical loaves of pure silicon are grown in an oven then sliced into wafers of 10 centimeters or larger. Although these PV cells have shown efficiencies of up to 24%, they are expensive to manufacture and would not be suitable for a competitive PV industry. Industry estimates show that sc-Si accounts for approximately 40% of PV sold.

Two alternative methods have been developed to reduce the manufacturing cost at the expense of cell efficiency: (a) the multi-crystalline method and (b) the string ribbon method. In the multi-crystalline (mc-Si) method, molten silicon is directly cast into a mold and allowed to solidify into an ingot. But the important difference is that the starting material can be a refined lower-grade silicon, rather that the higher semiconductor grade required for sc-Si material. Cells made from mc-Si account for more than 40% of PV sold. Combined, sc-Si and mc-Si account for more than 80% market share.

In the string ribbon method a pair of strings are drawn up through molten silicon pulling up a thin film. This technique does not waste much material, but the quality of silicon is not as high as that produced from the sc-Si or mc-Si methods. In addition to being expensive to manufacture, sc-Si and mc-Si cells are rigid, therefore not amenable to applications where different shapes may be desirable such as integrated building PV systems.

Amorphous silicon (a-Si) thin film cells are manufactured by vaporizing and depositing silicon material on low cost substrates such as glass, plastic or metal. Because the silicon atoms in an a-Si cell are not arranged in any particular order, they do not form crystalline structures and they contain large numbers of structural and bonding defects. This reduces their efficiency but they are much more economic to manufacture than sc-Si or mc-Si cells. Furthermore, a-Si absorbs solar radiation 40 times more efficiently than does single-crystal silicon. This means a film 1 micrometer thick can absorb 90% of the usable light energy shining on it. Cell efficiency of up to 13% has been reported. Amorphous silicon accounts for approximately 15% of PV sold.

CIGS and CdTe. These cells are also called **thin film** cells because of the method used to deposit the films in very thin, consecutive layers of atoms, molecules, or ions on a variety of substrates. These cells often use different semiconductor materials with an interface between the two in which the top layer is made of a different semiconductor material than the bottom semiconductor layer. The top layer is a window that allows almost all the light through to the absorbing layer below.

Thin film cells are made of semiconductor materials with different bandgaps so that up to 99% of light is absorbed, improving cell efficiency. The top or window layer in **copper indium gallium diselenide** (CIGS) devices is cadmium sulfide with small amounts of gallium added to the lower absorbing layer to boost the bandgap. Cell efficiency of up to 18% has been reported on cells fabricated by the physical vapor deposition method. Efficiencies of 12%-14% have been reported on cells fabricated by electro-deposition method.

In **cadmium telluride** (CdTe) based systems, cadmium sulfide acts as a thin window layer. Tin oxide is used as a transparent conducting oxide and antireflection coating. Thin film PV manufacturing processes have benefited from the semiconductor industry where many existing processes are adapted to fit the PV industry. Some of the methods include closed-space sublimation, electro-deposition and chemical vapor deposition. Efficiency of up to 16% has been reported on CdTe cell fabricated by metal-organic chemical vapor deposition and closed-space sublimation methods.

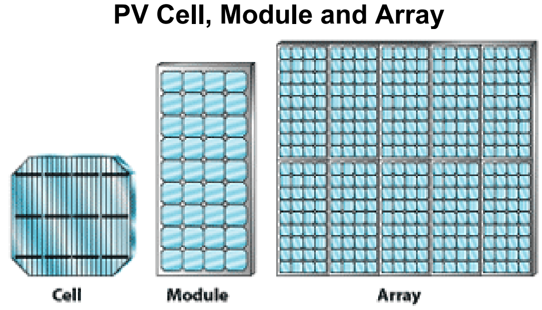
When competing with existing silicon-based cells, the challenges for the polycrystalline thin film cell technologies are several including cell efficiency, manufacturing cost (e.g. vacuum versus non-vacuum deposition technologies), perceived health risks of cadmium, and the competition for the supply of cadmium with the entrenched nickel-cadmium battery industry.

Dye-sensitized nano-structures. In recent years, PV cells based on technology that mimics the photosynthetic process has gained significant interest. This type of technology is based on the dye-sensitization of thin nano-crystalline films of titanium oxide (TiO_2) in contact with a non-aqueous electrolyte. These cells are simple and less expensive to fabricate than technologies described above. More importantly, the absorption characteristics of the dye can be changed by changing the color of the dye, allowing this technology to be applied in a wide variety of special applications. Up to 11% of cell efficiency has been reported. However, the overall module efficiency of current systems under development are only in the single digit range. There are still a number of technical hurdles to overcome, which will push the wider commercialization of this technology to the future.

In summary, silicon-based cells are expected to dominate the PV market for the foreseeable future. Within silicon-based PV cell manufacturing, the trend is towards mc-Si or a-Si because of the high cost of manufacturing pure silicon. Polycrystalline thin film technologies such as CIGS and CdTe have attracted significant attention but they still account for a small fraction of the market. With dye-sensitized PV cell technologies gaining interest from investors, polycrystalline thin film technologies will need to demonstrate a value proposition that is unique and compelling.

Business Models. Solar **cells** described above are the basic building blocks of a PV system. Because individual PV cells typically produce 1 or 2 watts of power, they are connected together to form larger units called **modules**. Modules are then connected together to form larger units called **arrays**. Arrays then become part of a PV system that also includes charge collectors, DC-AC inverters, batteries, and other power electronics components. The efficiency starts deteriorating as the electricity moves from cells to modules to arrays to complete systems.

PV Cell, Module and Array



Source: U.S. Department of Energy

Over time, a variety of business models have evolved, from pure cell manufacturers to vertically integrated companies that manufacture cells, arrays and provide installation services. Cell manufacturing is a capital intensive business. Consequently, energy companies, large diversified engineering companies and publicly traded pure play companies are in the cell manufacturing business. A whole host of companies are in the project development and systems integration business where these companies purchase cells and modules from PV manufacturers and integrate them for customers using purchased electronic components. We believe there is adequate competition in the PV cell and systems integration businesses. However, the power electronics segment is highly concentrated, where two or three companies account for a large share of the market, even though there are a number of PV inverter manufacturers.

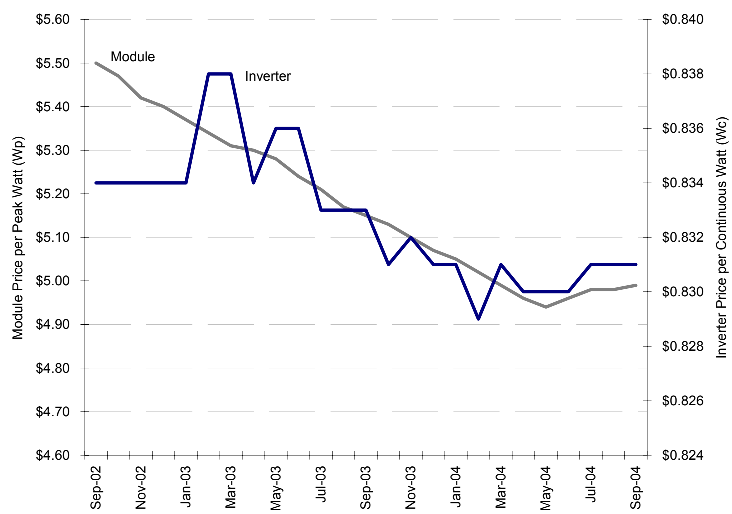
Technology Applications. The application of solar PV can generally be categorized as being either off-grid or on-grid. On-grid means that PV systems are connected with the utility electric system. For on-grid applications, PV systems need to comply with stringent utility and industry electrical interconnection and safety standards such a IEEE 1547 and UL 1741. On-grid PV must deal with utility rules that govern net metering and size of PV capacity (see net metering map above). With the average U.S. electricity price of approximately 7 cents per kWh, it is hard for PV systems to be competitive at current equipment cost without (a) subsidies or incentives; or (b) time of use pricing.

Off-grid applications are often necessitated by the lack of utility power, unreliability of the grid-supplied power, or the cost of alternative sources of power. These situations are prevalent in many developing countries where power is used for irrigation, lighting, healthcare, and other basic needs. Off-grid applications in more industrialized countries include backup power for telecommunications equipment, and powering of remote homes and offices. Off-grid applications in the consumer market include powering of digital watches, calculators and battery chargers.

The value to customers depends on the type of application, availability of alternatives, choice of technology and most importantly solar insolation.

Economics. The price of solar PV modules has declined by 9% in the last two years. However, the price of inverters has declined by only 0.4% during the same time period. Inverters account for as much as 10-15% of the combined cost of module, inverter and batteries.

Solar Module and Inverter Prices



Source: Solarbuzz Inc.

The economics of PV installations depend on a variety of factors including capital cost of equipment, installation cost, solar insolation, and most importantly the efficiency of the PV technology used. The efficiency of PV system is particularly important because to supply the same kW load, a less efficient PV system would require the purchase and installation of more modules than an efficient system. Unless the cost of the less efficient system compensates for its lack of inefficiency, it will not be able to compete with the more expensive, albeit more efficient system. The following simple example demonstrates this logic.

Solar insolation	700 W/m^2
Area available	100 m^2
Sunshine	6 hrs/day
Average load	5 kW
Total installed cost	$35,000 (@$7/Wp)
Total energy demand	43,800 kWh/yr
Average electric price	10 cents/kWh
Electricity cost	$4,380/yr
System Efficiency	15%
kWh produced/year	22,995
Savings	$2,300
Simple payback (years)	15

Let's say that a single crystal silicon based PV system is 15% efficient and costs $7 per Wp. At an average year round load of 5 kW, energy demand is 43,800 kWh and the installation cost is $35,000. In this example, the simple payback is 15 years. For a dye-sensitive nano-structure based PV system at 5% overall system efficiency to compete with the single crystal silicon system, its cost would have to be no more than $2.30 per Wp or a total cost of $11,500 or less. Similarly, for a polycrystalline PV (CIGS or CdTe) system with 10% overall efficiency to complete with the sc-Si system, the fully installed cost would have to be no more than $4.6 per Wp or a total cost of less than $23,000. These examples demonstrate the challenge faced by new technologies when introducing their products to the PV market currently dominated by silicon-based systems.

We believe that polycrystalline thin film, a-Si thin film and dye-based nano technologies have to improve both their efficiency and reduce their installed cost. Furthermore, it is not enough for just the PV manufacturers to reduce their cost. Since the overall cost of a PV system includes many other balance-of-plant components, other PV industry participants (particularly inverter manufacturers) will need to reduce their cost and improve efficiency as well.

Conclusion. The U.S. PV industry has experienced 30% annual growth in the last several years, mostly triggered by state renewable energy incentive programs. Similarly, federal-level subsidies, and easy interconnection and net-metering rules in Europe have encouraged a wider adoption of PV. This subsidy-induced growth has allowed economies of scale to be realized, which has led to about a 9% reduction in module cost over the last two years. Despite this growth and declining module prices, PV is still not mass-market ready. Regulatory and utility barriers still remain and costs are still high for wider adoption of this technology. The challenge for this industry is to generate profits without government incentives and subsidies. It is our belief that the next generation of technologies including concentrated PV can achieve these goals.

Authors' Certification

We, John J. McKenna, Himesh Dhungel, PhD and Ross F. Crawford certify that the views expressed in this report to the best of our knowledge, accurately reflect our personal views about the subject companies and their securities, and that we have not been, are not, and will not be receiving direct or indirect compensation in exchange for expressing the specific recommendations or views in this report.

John J. McKenna and Himesh Dhungel, PhD are both shareholders of STM Power, Inc.

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