PVGroup
an initiative of SEMI

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The Perfect Industry—
The Race to Excellence in PV Manufacturing

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INTRODUCTION

If we could envision it, what would the perfect PV industry look like?

Would it be able to sustain growth and profitability over 10, 20, even 50 years? Would it be a global industry, with open markets and common standards to reduce cost and spur innovation? Would it be an industry that's respected for its environmental, employment, public outreach and other business practices?

The truth is, the future is what we make it. Choices made today can impact the efficiency, sustainability, and profitability of the industry 10, 20, 50 years in the future.

If we dream. If we collaborate. If we act.

This White Paper will seek to define some of the desired characteristics of the future PV industry and what activities we all can take to help ensure they are realized. It is a snapshot of the vision that SEMI® PV Group members, PV Group Regional and Global Advisory Committees and other industry leaders have for the future state of the industry. Consequently, it is subject to change, elaboration, and refinement based upon member input and needs. The goal of this paper is to enrich the dialog of what we can do together, and how we can most positively impact the future. As a member-driven organization, actual activities, investments and initiatives will be developed, directed and overseen by member advisory committees and the Board of Directors.

THE PERFECT INDUSTRY

The following characteristics are offered as attributes of the ideal industry structure for the PV supply chain:

- **The Perfect Industry Sustains Long-Term Growth**

  Long-term growth requires open global markets supported with appropriate public policies (with or without incentives); the availability of raw materials, equipment, qualified people and supportive supply chain inventory management; and a limited set of global trade events that meet accelerate industry growth through diffusion of technologies and best practices.

- **The Perfect Industry Delivers Sustained Profitability**

  Sustained profitability requires appropriate industry standards to reduce unproductive product development costs; efficient access to customers to reduce sales and marketing costs; appropriate public policies to sustain a supportive business environment; a large, competitive global supplier base to deliver high quality materials, components and equipment at global best prices.

- **The Perfect Industry Practices Sustainable Development**

  A successful PV industry will be based on sustainable development principles to meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development in the PV industry can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability.

- **The Perfect Industry Is Global**

  Long-term growth and success of the PV industry largely depends on a strong, global supply chain and a sound understanding of an ever changing global market place. Materials and equipment vendors need access to customers around the world through open markets and common business practices.

Each of these attributes will be examined to understand their role in industrial formation, and to help understand the necessary industry actions required to achieve the greatest impact.

THE PERFECT INDUSTRY SUSTAINS LONG-TERM GROWTH

Imperative of Cost Reduction

To begin to frame the answer of what the perfect PV industry would look like, it may be useful to underscore the ultimate objectives in the PV industry's growth and success: reducing the world's dependence on fossil fuels and reducing the dangers of global warming. Beyond the economic imperatives of businesses, economies and consumers, the critical stakes in PV industry development involve human health and survival. It's what motivates government support, enhances the spark of scientific invention and accelerates consumer demand. The PV industry is not the semiconductor industry—or any other industry—and its importance goes beyond the economic well-being of its participants. The production of clean, renewable energy is of vital importance to every human being on the planet.

Given the high stakes in PV energy production, the overwhelming responsibility for the PV manufacturing supply chain is to deliver the lowest cost per kWh to the user. In other industries, cost reduction may be one of many other goals, such as quality, inventory management, product differentiation, environmental safety, etc. In PV, cost reduction rises above all. Equipment and materials companies understand this priority and embrace the challenge.

The importance of cost reduction arises from its direct relationship to solar power adoption and fossil fuel reduction. Reduce cost per kWh and more solar powered electricity will be generated and more fossil fuel will be replaced. And, because the life span of solar modules is 20 years and more, solar power's contribution to replacing fossil fuels is accumulative. Modules produced with today's technology won't get replaced with newer, more efficient technologies. Instead, they will keep on producing electricity and reducing reliance on fossil fuels. The faster industry-wide cost reductions can be achieved, the greater the long-term contribution to the global energy mix.

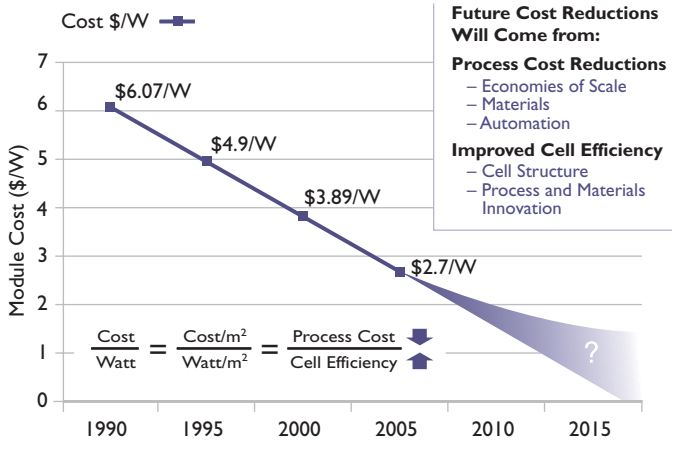
Figure 1 illustrates industry's cost reductions since 1990, resulting from both cell efficiency improvements and process cost reductions due to economies of scale, automation and materials improvements. The data illustrate what is in effect the industry learning curve or experience curve that the future growth of the industry will be based on (increasingly without government subsidies). Experience curves of 80–95% have been estimated in aerospace, shipbuilding, machine tools, and electronics manufacturing (NASA website http://cost.jsc.nasa.gov/learn.html). Unlike the semiconductor industry where Moore's Law has proven prescient, future cost reductions in PV are not as obvious. Learning curve effects or experience curve effects will be the result of a concerted effort by industry and individual companies, and unanticipated developments (i.e. disruptive technologies).

Edward Demming, the father of quality production theories, noted famously, that when people and organizations focus primarily on costs (an obvious management concern), surprisingly they tended to rise (because of hidden costs, waste and lack of product improvement). According to Demming, "Experience by itself teaches nothing." Through accelerating the diffusion of technical developments, through forums where Best Practices can be shared, and through collaborative cost reduction efforts in standards and other areas, the PV Group sees a major opportunity to assist the industry in achieving the steepest possible learning and experience curve.

Grid Parity

Grid parity—the point at which PV electricity is equal to or cheaper than grid power—will occur at different times around the world, depending on the amount of sunlight and the cost of electricity. This measure is essential to industry growth because roughly 90% of PV generating capacity consists of grid-tied electrical systems. Its associated measure, time to parity, depends on a fairly wide range of variables. Financial incentives, such as net metering and preferential feed-in tariffs for solar-generated electricity, have supported solar PV installations in many countries, including Germany, Japan and

Figure 1 PV Learning Curve

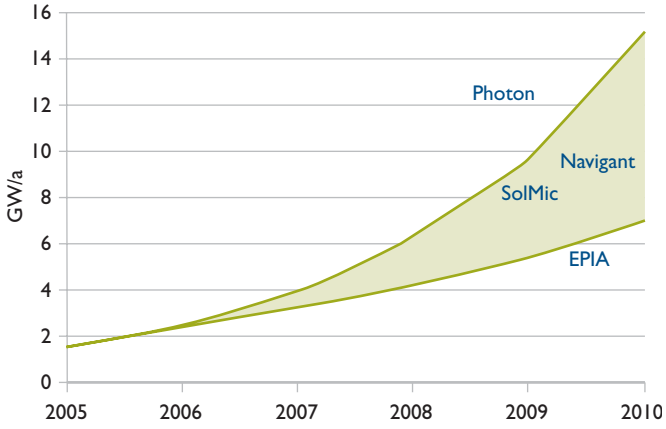


2002 Dollars Source: Navigant

the United States. Growth projections for PV vary wildly—from 7 GW to over 14 GW (Figure 2)—primarily due to uncertainties in the projected experience curve cost reductions, as well as assumptions about polysilicon supply and government subsidies. While technological developments can rarely be anticipated, experience curve improvements that will speed time to parity can be accelerated through an efficient, well-informed, global supply chain that expects continued growth.

Grid parity and long term PV industry growth will be driven by learning curve cost reductions enabled by process cost reduction (i.e. scale, automation) and improved cell efficiencies. Figure 3 provides a summary of laboratory demonstrated PV cell efficiency improvements by technology since 1975, as compiled by the National Renewable Energy Laboratory. Each of these technologies is well established in commercial markets and is expected to continue to be viable in various applications for the foreseeable future. In fact, technology diversity will increase in the industry with the mass production of III-V-based and dye sensitized solar cells anticipated by 2010 and organic and hybrid technologies later on. As indicated by Figure 3, all these technologies will have a unique learning curve comprised of the unique characteristics of their cell technology and manufacturing process. A common characteristic of all these technologies, however, will be dependence on a nimble, highly-sophisticated, highly-integrated advanced manufacturing supply chain. While many of the production processes may be highly proprietary and perhaps even vertically integrated, all will require the unique expertise of processing equipment manufacturers, materials suppliers, analytical and measurement specialists, automation experts, and other essential manufacturing and development providers.

Figure 2 **PV Market Forecasts**
The Spread

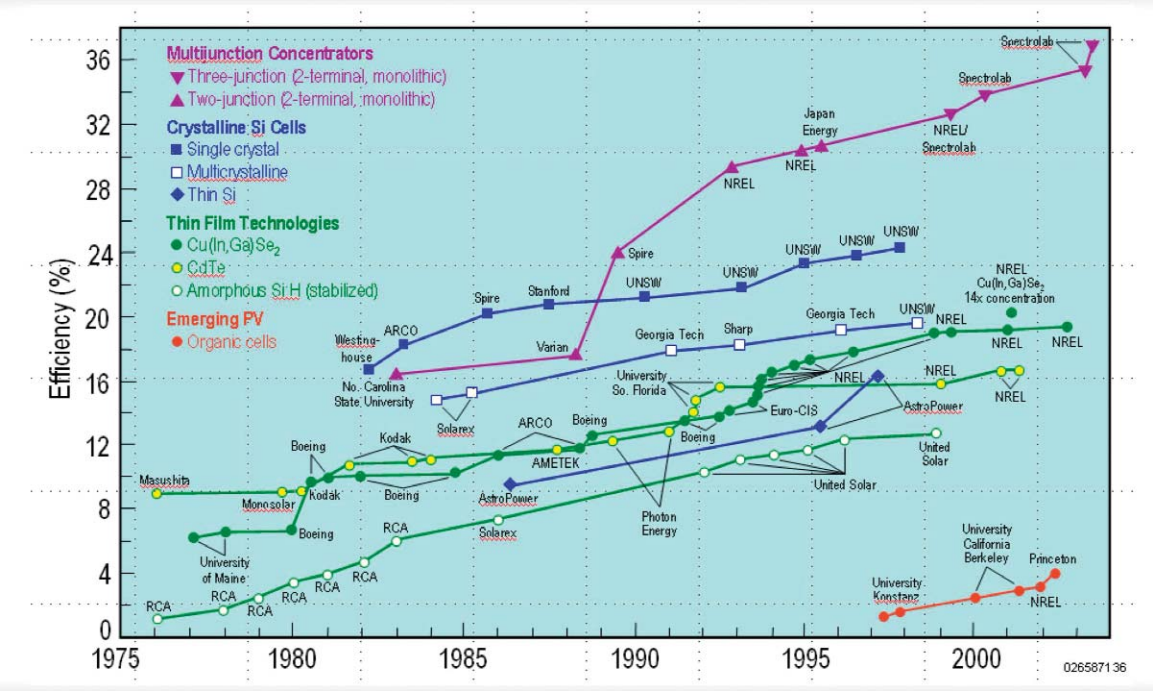


Source: SolMic

With grid parity comes investment. The impact of capital spending on annual solar module capacity can be estimated in the analysis presented in Figure 3. Driven primarily by cost reduction in this analysis (not rising electric power rates), the production ramp for PV modules can be critically influenced by the cost reduction and efficiency gains made today. Cost reductions and efficiency gains made one or two years earlier through an efficient, global marketplace will yield accumulative benefits into the future.

Consequently, because cost reduction involves direct and indirect costs of solar technology and the efficiency of the module itself, cost reduction in the PV industry involves both manufacturing excellence and technology transfer. The indus-

Figure 3 **Research to Commercialization**



Source: NREL http://www.nrel.gov/pv/thin_film/docs/kaz_best_research_cells.ppt#1

try requires not only equipment and materials that deliver increasing "faster, better, cheaper" results on existing processes, it requires new technologies and new processes to rapidly enter the global supply chain. And, while short-term cost reduction can be achieved through aggressive cost-cutting, long-term cost reduction requires innovation and investment.

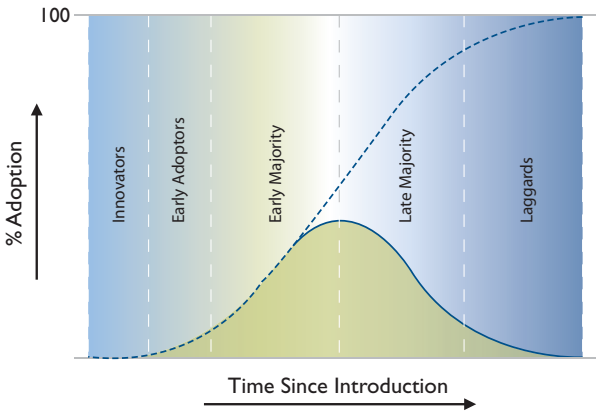
Growth and Market Development

Long-term industry growth in the PV industry requires the development of new geographic markets and new product and technology segments as they emerge. One of the most popular and enduring concepts in business today is the concept of technology adoption. Everett M. Rogers in his 1962 book, *Diffusion of Innovations,* theorized "that innovations would spread through society in an S curve," first by innovators, then early adopters, followed by the majority, until a technology or innovation is common (see Figure 4). The stages through which a technological innovation passes are:

- Knowledge (exposure to its existence, and understanding of its functions)
- Persuasion (the forming of a favorable attitude to it)
- Decision (commitment to its adoption)
- Implementation (putting it to use)
- Confirmation (reinforcement based on positive outcomes from it)

Long-term growth in any industry requires the efficient transformation of innovation from discovery through widespread adoption. Important innovations also often require diffusion of new technologies, applications and processes through entire supply chains before they yield customer value. In the computer industry, for example, innovations in manufacturing have enabled rapid product life cycles of new processors that have accelerated advanced software applications for gaming and enterprise management. Industry growth has also been supported through the emergence of the Internet and broadband communications that require global handshaking and communications protocols, and software standards such as Java and Web 2.0.

Figure 4 Diffusion of Technologies



Today, the computer industry is seeking new growth opportunities in video, mobility and wireless communications, each one requiring a rapid adoption of new technologies and paradigms through the supply chain (i.e. chip makers, software developers, OEM manufacturers, communications infrastructure, content providers, etc.). Without active, supply chain collaboration and industry standards to enable the development of new applications, new features and new products, the computer industry would not have sustained growth through the last 30 years.

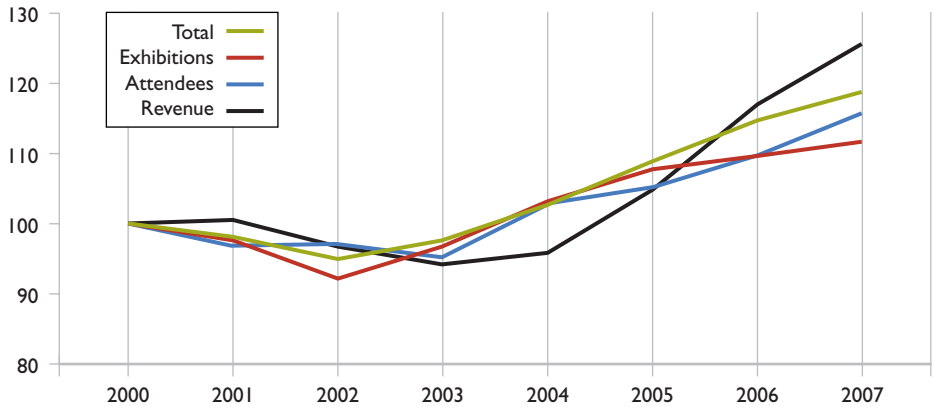
Market development also requires opening new geographic markets for both manufacturing and deployment of solar technology. Many new industries require infrastructure to grow and prosper that may comprise education and workforce development, positive investment climate, supportive government policies, and industrial partnerships. For example, in the semiconductor industry, SEMI has been active in the development of new manufacturing regions by providing advice and council, facilitating collaborations, organizing trade missions, and other activities necessary to integrate market forces, governmental economic policy, education and human capital programs, and financial support. SEMI has been active in China since the early 1980s, working with members, the Chinese government and other organizations to create a dynamic semiconductor and FPD manufacturing region. Beginning as a small market dependent on government funding and used equipment, China's semiconductor equipment market today exceeds $4 billion per year and display manufacturing market could eventually account for 20–30% of the total world market for TFT-LCD manufacturing equipment. Both markets required early, ongoing and comprehensive government relations activities to encourage and sustain these impressive growth rates.

The Role of Trade Shows and Conferences in Industry Development

Trade shows and conferences are essential to accelerate the diffusion of technology. They promote the latest scientific developments, engineering advances, product developments and support solutions. They enable the dissemination of the latest technical information and Best Practices, and facilitate the formation of professional and business collaborations. Successful events give voice to customer needs, proof to vendor claims and enable dialog and information exchange. Effective expositions and trade shows engage all sectors of the supply chain — including finance, education, government — exposing dependencies and synergies.

Trade shows and conferences are essential components of any growing and vital industry. Worldwide, over 13,000 exhibitions a year held in more than 2,000 venues that are supported by 1.5 million exhibiting companies. Over 75 million attendees visit trade shows to evaluate new products, find new suppliers and advance their professional careers. Trade shows and exhibitions continue to grow despite the emergence of alternatives such as teleconferencing and Web marketing (see Figure 5, page 5). According to the Center of Exhibition Industry Research (CEIR), trade shows have experienced a compound annual average growth rate of 2.5% for the 2000–2007 period.

Figure 5 **Exhibitions Industry**



Source: Center for Exhibition Research

The reason trade shows have grown is that they remain the most valuable form of sales acceleration for business-to-business firms. A major study by CEIR concluded that exhibitions play a key role in marketing products, ranking second only to direct sales and ahead of advertising, direct mail and public relations. Most importantly, the biggest news from the research project found that exhibitions rank second only to direct sales with respect to each stage of the selling process—from the customer's initial determination of need to the final purchase of product. Along with direct sales (which includes some exhibition activity), exhibitions were measured against advertising, direct mail, public relations and telemarketing.

These same values for exhibitors are present in the PV industry. Attendees and exhibitors have unique and specific objectives in participating in trade events that will vary by geography, industry segment, job title, and other factors. These objectives are not identical. Exhibitors want to lower their overall cost of sales and effectively differentiate their companies and products from competitors. Attendees want an opportunity to identify and evaluate new products and suppliers that will benefit their company and careers. Large exhibitors want fewer events to reduce costs; smaller, specialized companies want targeted expositions dedicated to their niche. Attendees want local trade shows in attractive destinations and venues because 80–90% of buyers and specifiers cannot travel internationally and want events highly tailored to their job function, specialty and company role.

The equilibrium between attendees' needs for local and specialized events and exhibitors' desires for limited number of horizontal events will be realized by market forces—what attendees and exhibitors will support. But large industry events accomplish other goals not precisely defined by the economic imperatives of buyer/seller relationships. Industry expositions play an important role in diffusing technology and best practices, bringing visibility to cost, cycle time and productivity opportunities rapidly to worldwide audiences. They provide for important education and workforce development benefits through seminars and training. They bring visibility and access to investors and facilitate capital and financing solutions for the industry. Successful trade events also accelerate the dissemination of essential legal, environmental, public policy and other information to the industry.

Non-profit associations have long been recognized as an efficient and effective alternative to private trade show companies for managing industry exhibitions. According to a 1994 study by the Convention Industry Council, association-sponsored

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The PV Group goal in expositions for the PV industry is to rationalize the global event calendar and improve the value of existing trade shows for its members. The PV Group is accomplishing this goal through extending the role of worldwide SEMICON® events to also address the PV market, partnering with established exhibitions such as Intersolar to ensure the highest possible value for members, and partnering with other industry associations such as JPEA, SEIA and EPIA. These activities are conducted through the oversight of regional and global PV Group advisory bodies comprised of member companies. By advocating member interests in the management of existing events, the PV Group can best assure that member value and industry growth can be accomplished.

The PV Group goal in managing and co-managing PV events is to put the interests of the attendee and exhibitor first and maximize the value for PV Group member companies. To accomplish this goal, PV Group priorities will be focused on attracting high-value attendees, accelerating the diffusion of new technologies and product life cycles through program content, and improving the productivity of the industry through access to Best Practices information. As an event manager and co-manager, the PV Group will comply with all world-class show management guidelines, standards and practices.

events generated $56.1 billion in economic benefits, or 68% of the industry total. Another study by the Council indicated that association conferences result in higher attendance than those organized by the private sector. There are many reasons for this result, including favorable tax benefits, ability to generate industry support, and position to be "first-mover" in creating new events for emerging industries. A significant reason for the success of association sponsored events is also their ability to assure low or lower costs to exhibitors due to the presence of member oversight by the association. Unlike private firms, association events provide designated member/exhibitors with complete financial transparency on costs, fees and profits.

Another positive outcome to industry expositions managed by non-profit associations is their ability to manage events for the "greater good" of the industry, rather than profit maximization. Association sponsored events typically provide programs, rooms, agendas, booths, and other resources to non-profitable event activities. Positive margins made on industry events are also typically invested in other areas of association activities such as government relations, standards, public education and other activities. Any money made on association sponsored events stay in the industry.

THE PERFECT INDUSTRY DELIVERS SUSTAINED PROFITABILITY

Industry Standards: Accelerating Cost Reduction

In technology markets, long-term sustained profitability in the supply chain requires that research and product development costs be concentrated on innovation. In many industries, R&D investments are consumed by product differentiation, such as accommodating special regional or customer-specific requirements. In the PV industry, industry-wide cost reductions, in combination with a sufficiently profitable supply chain, can only be achieved through materials and process innovation, productivity improvements and effective global industry standards. While product differentiation is necessary on the deployment side of the PV supply chain where market-specific products comprise a major portion of the industry, equipment and materials suppliers require meaningful, effective and global industry standards to enable maximum investment in innovation.

Industry standards enable innovation through reduced costs on equipment physical and communications interfaces, product specifications and nomenclature, health and safety requirements, and a host of other product differentiators that add no value or benefit to the end product or user. To achieve the growth goals for the industry, standards play an important role by channeling development activities into real innovation, not supporting a fractionated industry with custom sizes, shapes, features, interfaces, quality, and other attributes that are not essential to long-term end customer value.

The significant economic value of standards to an industrial growth has been demonstrated in many studies. A study of the Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, and Dresden Technical University have shown standards to have a positive effect on Germany's economic growth and its international competitiveness, contributing as much as 1% of gross national product. According to Fraunhofer, "As, for the overall economic development, it is not only the potential of existing innovations that is of importance, but also particularly their diffusion. Here, the standards play a decisive part. They act as catalysts enabling the diffusion of innovations in the market." (*Fraunhofer ISI*, July 31, 2000)

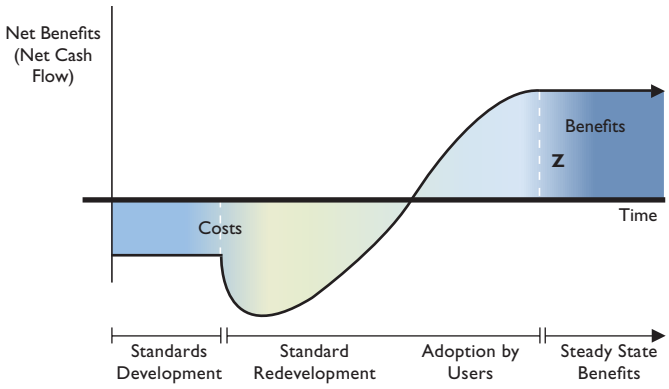
In addition, the Fraunhofer scientists detected a significantly positive relation between patent applications and output of technical regulations. In innovative fields, considerably more new standards are developed than in less innovative ones, indicating that standardization orientates itself by the demands and challenges of technical progress.

Figure 6 illustrates how effective standards provide long-term cost reduction for entire industries. This flow can be seen in many segments in the semiconductor industry including wafers, processing materials, wafer processing equipment, metrology and measurement, packaging, and test.

For example, the National Institute of Standards & Technology (NIST) conducted a major study on the economic impact of measurement in the semiconductor industry, including the value of associated standards (Planning Report 07-2, *Economic Impact of Measurement in the Semiconductor Industry,* prepared by: RTI International for NIST, December 2007). The study concluded that investments in software standards and interoperability in measurement alone will result in approximately $2 billion in benefits for the period of 1996–2011.

New calibration and standard test methods helped generate another nearly $7.6 billion in benefits for the same period. These investments mainly affected the scrap rate ($7.3 billion

Figure 6 Flow of Costs and Benefits



in benefits attributed). Virtually every instrument and process tool used in the semiconductor manufacturing is calibrated frequently to ensure consistency and accuracy. These adjustments compensate for long-term drifts in the equipment that often arise because of aging. The calibration process is extremely important to overall product quality because uncompensated drifts in process, test, and QA equipment will contribute to out-of-control processes and lower yields. Proper equipment calibration uses standard reference materials (SRMs) and standard test methods to return the equipment to factory specifications. SRMs and standards are a critical part of metrology since they establish a "yardstick" for comparison of data taken by different methods, by similar instruments at different locations. The PV industry has nearly similar needs as the semiconductor industry for calibration and standard test methods.

The nearly $10 billion in industry savings in measurement standards are only one area of standards contributions to the semiconductor industry. Other major areas of standards contributions to the industry include: assembly & packaging, micropatterning, liquids and gases, test equipment, physical interfaces and carriers, environmental health and safety, traceability, and silicon wafers. Many of these areas have been extended to the FPD industry with important revisions and modifications managed directly by FPD stakeholders, with important differences from comparable standards in the semiconductor industry.

A common threat to industry standards are competing and conflicting standards, often promoted by governments to nurture domestic industries. If this occurs in the PV industry, significant costs to the industry and barriers to PV deployment rates will occur. In an industry dedicated to reducing fossil fuel use, the stakes are too high to allow effective international standards to be sacrificed to protect a regional PV supply chain.

At the first PV Group Committee meeting in early September 2006, executives from the industry gathered together to discuss where the association could contribute most to the growth of the PV industry. One of the major elements mentioned was the need for industry standards at the manufacturing equipment and materials level. Dr. Ossenbrink, Unit Head Renewable Energies of the European Commission Joint Research Center stated, "Standards in photovoltaic are essential for the industry in order to lower trade barriers and to reduce the cost of ownership for cell and module manufacturers of their production facilities. Both elements are key to reach competitiveness of the photovoltaic industry in a global energy market."

PV Group Standards Policy 9/15/08

Industry standards activities are desperately needed in the PV industry to reduce cost and accelerate investment in innovation. Although some standards are applicable, the PV industry has been dominated by de-facto standards from dominant players or by no standards at all.

SEMI International Standards are in a unique position to accelerate appropriate standards activities for the PV industry. First, many semiconductor standards are immediately applicable to the PV industry. Materials and equipment suppliers who serve display, semiconductor and PV industries do not want to support a new set of communication protocols, labeling requirements, testing metrics, physical interfaces and other features where they add no value to the customer. Second, SEMI International Standards has a proven standards development process with a 35 year history promulgating over 800 standards and safety guidelines, many directly applicable. Third, PV Group member companies have demanded effective standards for the industry.

In order to become a cost effective energy source, any inefficiency such as buffer-stock, change of carrier, machine-to-machine communication and process observables for advanced process control needs to be eliminated or reduced to their basic minimum. Many semiconductor equipment manufacturers that have diversified their product mix to PV are using some existing SEMI standards. But the PV equipment and materials industry has to intensify the standardization effort in order to generate additional industry-wide cost reductions. Like FPD industry standards, PV standards effort must be for, and by, the PV industry. They need to be managed by independent committees comprised of PV industry representatives whose interest lies with the solar power industry.

PV Group is committed to PV industry standards development in order to enable and accelerate this process. Key market players have been assembled to address this global industry need. PV standards committees in North America, Taiwan and Europe have been assembled with task forces and working groups on equipment interface specifications (PV EIS), silicon wafers, gases/liquid chemicals, and test methods for impurity concentrations for PV silicon feedstock.

These standards must accelerate and broaden to yield the industry wide cost reductions and the long-term sustained profitability of the supply chain. Without effective global standards, the industry innovation will slow, globalization will diminish, PV grid parity will be delayed, and the world will suffer.

SEMI International Standards will continue to engage in a number of outreach activities with other standards organizations to benchmark world-class standards practices, harmonize PV Group initiatives with other groups around the world, and avoid duplication and conflict. Today, there are now over 1,800 registered individuals in the SEMI International Standards Program, representing more than 880 companies and organizations in 36 countries. Nearly 800 SEMI Standards and Safety Guidelines exist, available in multiple languages. SEMI International Standards Program is in the late stages of acquiring accreditation by the American National Standards Institute (ANSI), the U.S. member body to ISO and IEC. It has been granted formal liaison with IEC TC 113 on Nanotechnologies. SEMI is well recognized as a peer standards developing organization (SDO) and enjoys collaborative, working relationships with ASTM, IEC, IEEE, ISO, OECD, VAMAS and others.

SUSTAINING PROFITABILITY THROUGH REDUCING AND SHARING RISK

Healthy, vibrant industries have confident insights into the future of their industry through access to accurate market data, efficient global communications, and regulatory/public policy stability facilitated through well-informed policy makers. Currently, over 10,000 industry trade organizations exist in the world. Their role is to reduce risk and total costs for their members, through a variety of activities, including public policy advocacy, workforce development, public education, and market statistics development.

Associations are effective in these areas because it is impossible for most companies to invest the time and money educating policy makers on industry needs. Associations are often effective in providing market statistics programs for their members because of their trusted ability to collect and handle proprietary company data. By enabling informed investment decisions by members, and informed public policy decisions by government decision-makers, entire industries can reduce risk and efficiently share costs to address common needs.

Typical data programs managed by industry associations include market size and growth rates, often segmented by total bookings and billings for selected markets or product segments. These programs enable member companies the ability to verify their individual market share without losing proprietary information. Other data programs may investigate scope and size of industry threats and opportunities. By pooling resources among many similar companies for common research initiatives, industries are better able to reduce risk and optimize investment opportunities.

The PV industry needs accurate and reliable market research and information to sustain high growth and profitability. Much of the research the industry uses will be provided by market research firms, financial analysts, consultants and other private and public firms. Like many industries, the PV market will benefit from collaborative market research and statistics programs by industry associations that provide mutually beneficial insights and intelligence without compromising proprietary information.

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The PV Group is committed to supporting members by developing market research and statistics programs, and collaborating with other associations to influence and support their public policy interests. The PV Group will maintain active, effective and representative advisory boards and working groups to validate member needs and operate under the oversight of a Board of Directors to prioritize and fund programs and provide operational input and guidance.

Enabling more informed investment and strategic planning decisions through market research and statistics activities has long been an important service to SEMI members. SEMI maintains active market research programs in all the segments it serves, helping guide research, development, and market expansion investments by its members. The Book-to-Bill report provides a first look at the book-to-bill ratio for North American headquartered semiconductor equipment manufacturers. SEMI collaborates with the Semiconductor Equipment Association of Japan (SEAJ) who also collect and disseminate a book-to-bill report using similar methodology. SEMI also conducts periodic, special studies on topics ranging from Used Equipment Markets in China, Intellectual Property Protection, R&D Funding, and other subjects.

The PV Group is currently working directly with members and other associations to develop a global PV equipment and materials Book-to-Bill report for the PV industry. The PV Group is also working to develop reliable market statistics on polysilicon supply that help suppliers plan for capacity increases and buyers gauge the need for new suppliers and contracts. The PV Group is also conducting needs assessments with members for other market research and intelligence activities. It is the PV Group's intention to work with a variety of research organizations and build upon existing industry data collection activities, concentrating essential and value-added information specifically needed by the manufacturing supply chain.

The PV Group is committed to working with other associations such as EPIA, JPEA and SEIA to advance the interests of its members in legislative and regulatory affairs. The PV Group will participate in coalitions with other industry groups to support member public policy interests and work to keep members informed of important public policy matters. The PV Group will work with members to assure that the unique expertise and interests of the manufacturing supply chain is properly integrated into the legislative and regulatory process so that decisions makers are well informed.

In industry advocacy, workforce development, public education, and public policy, the PV Group is drawing upon SEMI staff and a history of successful collaborations with other industry groups to identify and serve members. The process of identifying programs, allocating staff, prioritizing and funding programs is conducted under the guidance and oversight of both regional and global PV advisory boards, and a Board of Directors comprised of member companies. As new initiatives and programs are identified, these governance structures will be utilized to ensure that member interests are met in the most effective and most representative way possible.

Figure 7 **What Should Your Association Do? Associations' Programs and Activities Percentage of Budget**

Programs/Activities	Average % of Budget Spent on Activity
Standards and Ethics	
• Defining product and service standards and promulgating them to members, non-members, and the general public	8.3%
• Defining standards for professional certification and promulgating them to members, non-members, and the general public	6.6%
• Formally certifying individual professional achievement	8.6%
• Formulating or promulgating ethical or performance standards for members, or for non-members within the activity the association covers	6.3%
• Enforcing ethical or performance standards for members, or non-members within the activity the association covers	5.4%
• Establishing voluntary environmental standards and compliance programs	4.8%
Education	
• Offering education programs for members	18.4%
• Engaging in public information and public education activities	8.9%
• Political engagement	
• Political education and training for association members	5.5%
• Grassroots member contact programs to have members contact local, state, or federal legislators	5.3%
Lobbying	13.5%
• Sponsoring issue advocacy print, radio, or TV advertising	4.9%
Community Service	
• Sponsoring community programs conducted by association members (e.g., volunteer teaching in public schools)	7.0%
• Making direct or matching charitable contributions	5.3%

Source: Value of Associations—2005 Survey

Healthy, growing industries are also served by effective industry education and workforce development programs. Many industry associations devote significant time and resources to providing valuable education and training for their members. They also collaborate with educational institutions to ensure curriculums are aligned with industry needs, conduct salary surveys, provide job posting services, advocate public policies that advance education funding, promote fair immigration, and support other workforce development activities. Many industries provide or facilitate certification programs to ensure a highly competent workforce that can consistently meet minimum standards.

Beyond the education and training of the workforce, many industries provide vital information and educational materials for the general public. These activities support community relations and public policy goals that benefit all companies in the industry in the form of higher market valuations, factory location flexibility, enhance workforce recruitment, and lower permitting and regulatory compliance costs.

Perfect industries pool their resources to engage with regulatory, legislative and other government organizations to advance their collective interests. In today's highly complex, regulated, interdependent and global marketplace, few companies can successfully protect and advance their interests before local, regional, national, and global institutions without collaborating with similar firms of comparable interests.

Successful industries also have established processes and mechanisms for working with other industries and organizations. In the semiconductor and flat panel industries, for example, industry progress is facilitated through collaborations with the information technology, software, nanotechnology, MEMS, chemical, PV, photonics, and other industries, each served by different standards bodies, trade groups, and industry associations. Industry growth is also facilitated through collaborations with professional societies and organizations such as IEEE, ANSI, and SPIE. Global industries are able to extend these collaborations with multiple institutions around the globe.

Prosperous, respected industries are characterized by companies that work effectively together to share cost and reduce risk. They are characterized by organizations and institutions—ongoing and of short duration—established specifically to identify and deliver shared benefits that would be too costly for any one firm to ensure. These organizations and institutions have fair, representative and credible decision-making structures that identify useful programs, prioritize activities, allocate funding, and provide proper oversight.

THE PERFECT INDUSTRY PRACTICES SUSTAINABLE DEVELOPMENT

The PV industry is over 30 years old and is based on a rich legacy of environmental insights and values. Many of the early contributors to the industry's growth and achievements were motivated by the desire to see the benefits of clean, renewable energy become widely enjoyed. They had the foresight to question continued reliance on fossil fuels and the vision to see the major role that solar powered electricity would have in our energy future. This legacy will always be fundamental part of the PV industry; it plays a major role in advancing supportive public policies, generating investment capital and attracting the best and brightest people to the industry. Maintaining and building upon this legacy will require collaborative industry efforts that are coordinated globally. Only by working together — across borders and across the supply chain — can we ensure this legacy is preserved.

But the forces unleashed by the exploding worldwide solar market are threatening this legacy. A rush to market can lead to ethical and environmental short comings. The imperative of cost reduction can threaten the values that founded the industry. The regulatory and legal differences between countries can provide undesirable sources of competitive advantage. Initiatives like PV CYCLE in Europe show the importance this industry is assigning to voluntary compliance to REACH regulations, and they set a benchmark for other regions. Unless the industry collaborates globally, the support of governments, the cooperation with communities, and the attractiveness and appeal to investors and employees will be threatened.

An example of the complex interrelationships between sustainable development practices worldwide can be seen in the emerging polysilicon industry in China. In March 2008, in news reports carried worldwide, it was reported that a Chinese company was improperly discharging hazardous waste byproducts of polysilicon production directly into community water sources and landfills. The report said, "There is money to be made and in China, polysilicon plants are the new dot-coms. Flush with venture capital and with generous grants and low-interest loans from a central government touting its efforts to seek clean energy alternatives, more than 20 Chinese companies are starting polysilicon manufacturing plants … (but) solar plants in China have not installed technology to prevent pollutants from getting into the environment or have not brought those systems fully online." (Washington Post Foreign Service, March 9, 2008; A01)

The report generated widespread outrage from environmentalists and legislators worldwide. Questions such as, "Why should we pass government solar power incentives, when the money will ultimately be sent to China to support intolerable production practices?" Others may have asked, "Why should we invest in polysilicon production in the United States or Europe that would require expensive pollution abatement systems when my competition in China or elsewhere does not have to?"

In fact, some of the loudest outrage came from other China polysilicon producers who do practice globally acceptable practices and understand the need to serve global customers without sacrificing environmental quality and ethical business practices. They see the entire industry — producers, customers, domestic and international — damaged by the alleged practices of one company.

The perfect industry would have mechanisms that would reduce and eliminate unethical and non-sustainable practices.

In the mid-1980s, residents in California's Silicon Valley brought a civil suit against five semiconductor industry leaders, including IBM, for massively polluting groundwater. "It was a public relations disaster, even without the big financial hit those companies took to clean up the mess," says Pam Gordon, president of Technology Forecasters, which consults with semiconductor firms on environmental issues. (*Electronic Business*, 6/1/2005).

Twenty years later, semiconductor firms win environmental awards and are widely referred as benchmarks touted for responsible environmental responsibility. Having radically reduced groundwater pollution and greenhouse gas emissions, the industry is now poised to tackle the problem of lead-free manufacturing initiatives and mandatory recycling requirements. (*Electronic Business*, 6/1/2005).

The difference between the two eras is characterized by today's near universal collaboration to share environmental best practices and reach world-class levels of environmental responsibility. Today, the semiconductor industry is not only recognized worldwide as a "good citizen," it is an industry that has radically lowered costs on regulatory compliance, energy usage, fossil fuel emissions, and workplace safety through effective collaboration.

To be an efficient and environmentally responsible industry, the PV supply chain needs an equal if not more effective collaboration mechanisms to address sustainable development opportunities on a global basis. One increasingly common practice for such as a collaboration is the green supply chain.

A Green Sustainable Supply Chain can be defined as "the process of using environmentally friendly inputs and transforming these inputs through change agents — whose byproducts can improve or be recycled within the existing environment. This process develops outputs that can be reclaimed and re-used at the end of their life-cycle, thus creating a sustainable supply chain." (*The Green Supply Chain*, August 7, 2007 *Sustainability Can Be a Competitive Advantage,* by Patrick Penfield Whitman School of Management, Syracuse University) The goal of a sustainable supply chain is to reduce costs while helping the environment.

Sustainable supply chains are practical necessities in this era where companies are being held accountable for environmental problems created by suppliers. Companies of all sizes are

enhancing their supplier relationships by encouraging and mandating business practices that have significant impact on environmental practices, such as:

- Reducing the obsolescence and waste of maintenance, repair and operating (MRO) materials through enhanced sourcing and inventory management practices.
- Substantially decreasing the costs associated with scrap and material losses.
- Decreasing the use and waste of solvents, paints, and other chemicals through chemical service partnerships.
- Recovering valuable materials and assets through efficient product take back programs.
- Lowering the training, material handling, and other extra expenses associated with hazardous materials.
- Increasing revenues by converting wastes to by-products.
- Reducing the use of hazardous materials through more timely and accurate materials tracking and reporting systems.

There is growing evidence that an increasing number of companies are moving from green rhetoric to sustainable action. In a recent report, *Building a Green Supply Chain: Social Responsibility for Fun and Profit,* Aberdeen Group benchmarked the green supply chain initiatives of over 350 firms, worldwide. The study found that 83 percent of respondents have completed or are planning the green-focused redesign of all or key areas of their supply chains. As Figures 8 and 9 indicate, companies have a variety of objectives for performing supply chain network redesign—ranging from cost reduction to improved social responsibility.

For the PV industry, the choice becomes whether cell makers and suppliers proceed with sustainable development on an individual company basis, or whether to proceed uniformly in a consistent, high quality and lower cost approach. Currently, many large companies have instituted green supply chain programs that may provide competitive advantage over competitors. For example, Taiwan-based AUO in the flat panel display industry operates a world-class green supply chain program that requires extensive reporting and operations conformance of suppliers to participate. Suppliers to AUO must meet their green procedures and a different set of procedures at Chi Mei Electronics, LG Philips, Samsung and other major FPD suppliers.

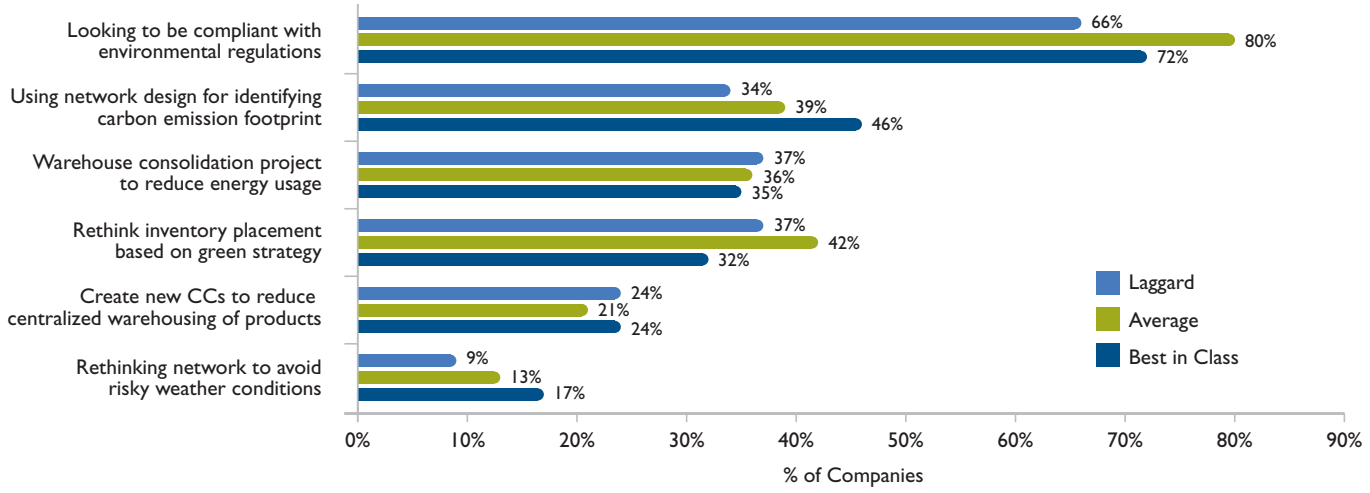
Hewlett-Packard, IBM, Dell, Solectron and Flextronics have launched an Electronics Industry Code of Conduct, which establishes minimum industry standards for social responsibility and environmental impact. The primary goal of the effort is to eliminate suppliers that can't conform to the code. Another initiative is based on ISO 14001 and 14000 guidelines.

ISO 14001 is the international specification for an environmental management system (EMS). It specifies requirements for establishing an environmental policy, determining environmental aspects and impacts of products/activities/services, planning environmental objectives and measurable

Figure 8 **Top Five Goals of Green Supply Chain Re-Design**

Reduce Overall Business Costs	56%
Enhance Company Social Responsibility	51%
Improve Visibility into Green Supply Chain Drivers	49%
Improve Profits	42%
Reduce Waste/Improve Disposal Methods	38%

Figure 9 **Objective of Green Supply Chain Network Design Activities**



targets, implementation and operation of programs to meet objectives and targets, checking and corrective action, and management review.

ISO 14000 is similar to ISO 9000 quality management in that both pertain to the process (the comprehensive outcome of how a product is produced) rather than to the product itself. The overall idea is to establish an organized approach to systematically reduce the impact of the environmental aspects which an organization can control.

Sharp, for example, has a comprehensive set of requirements compiled in a document, The Sharp Supply-Chain Corporate Social Responsibility (CSR) Deployment Guidebook that outlines 39 items in seven areas. Q-Cells procurement policy states: "The consequences of our present and future activities in relation to the environment are permanently being reviewed, monitored and evaluated. Emissions and waste are constantly being reduced. The economical deployment of natural resources, such as silicon, water and energy, and their recycling are duly taken into consideration."

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For the PV industry, the challenge is to reconcile and harmonize EHS and sustainable supply standards, guidelines and practices to allow the industry to reach high levels of performance without excessive costs or redundant or conflicting requirements. This is a major challenge for a global industry with hundreds of key participants based in over two dozen countries. This is an effort that must emerge from the PV supply chain and serve the needs of cell and module makers, equipment, materials, and component suppliers. It must deal with specific and unique PV industry issues, yet leverage best practices from other industries.

The perfect industry will have green supply chain management practices that are standardized across continents and countries, managed and facilitated through fair and open practices, yielding dramatic cost efficiencies, and delivering the highest value industry reputation.

THE PERFECT INDUSTRY IS GLOBAL

With the advent of the integrated circuit (IC), the world became a bigger place. Over the past 40 years, the understanding and perception of technology in the general public changed rapidly and significantly with the use of computers, phones, iPods and other devices which are manufactured and assembled in many different regions of the world. The vast majority of consumers don't know where their latest gadget was made or what key suppliers enabled their critical features and price points.

To support the ever-increasing desire for faster, cheaper, and more sophisticated devices, technology providers had to create a strong, reliable, multi-facetted supply chain to ensure that increasing demands for a large variety of products are met with consistent quality and adequate price. Add to this the international labor, education and skill development requirements in new and emerging technologies, and the result is what Accenture called in their 2006 Supply Chain Management study "… competitive necessities, as well as core strategies for managing costs." Regions, which 40 years ago where underdeveloped with fledgling economic growth, have since become major, sometimes dominant, players.

What does it take to achieve profitability in a complex, global supply chain? How can each segment ensure its own survival and growth while being dependent of others? One ingredient is a global network that shares the same objectives with respect to quality, cost reduction, environmental practices, business ethics, open markets, and code of conduct. Another is understanding and integrating global market needs when it comes to designing and developing global strategies (i.e. realizing early in the process that one supply chain element impacts others). The third critical aspect is risk management and risk reduction throughout the supply chain.

Developing and continuously improving and strengthening the global supply chain in the PV industry are critical to its survival. Demand for materials for both crystalline and thin film cell and module manufacturing is on a steep rise, and quality control, steady supply, and proper environmental practices are among the main challenges the industry is facing right now. Will the industry progress without future supply chain disruptions, or will it experience "boom and bust cycles" similar to the semiconductor industry? Can the industry meet the current shortages without sacrificing environmental and quality standards? With restrictions on Cadmium through RoHS regulations, the popularity of industrial recycling regulations such as REACH, and the emergence of III-V, nanotechnology and other new materials, the regulatory environment can only be expected to become more complex.

As government policies, fossil fuel prices and other factors create more and more market opportunities around the world, equipment and materials suppliers want to respond with the most advanced solutions and best prices. They want to leverage the technology learning curve to deliver continuously improving products with more valuable features and benefits. This can only happen with open markets that are well informed of the latest technologies, the most effective equipment and materials solutions, the most productive and responsible Best Practices to develop and deploy PV products. Requiring the supply chain to invest in specialized and unproductive practices for every region and every country as the grid parity becomes imminent around the world will hinder the growth of the PV industry. Many high technology markets in virtually every sector—wired and wireless communications, entertainment, industrial—are hindered today by a variety of economic development

and regional supply chain competitions. A fractionated world market with competing standards, conflicting industrial regulation, protective government policies are also threatening the PV industry and exacerbating the global warming crisis.

A PV industry committed to long-term growth will be a global industry supported by global standards and open markets. A sustainable industry committed to long-term, profitable growth will be one with harmonized standards for environmental, health and safety standards and guidelines that yield high-quality, low-cost products from any manufacturing location in the world.

PV GROUP: FOLLOWING USEFUL MODELS TO CREATE THE PERFECT PV INDUSTRY

In semiconductors, the industry has been following Moore's Law almost from its inception. First observed by Gordon Moore, the co-founder of Intel, the law states the number of transistors that can be placed in the same area on an integrated circuit will double approximately every two years. This doubling of transistors every two years corresponds to the cost reductions that have proliferated electronics into every part of our lives. The trend has continued for more than half a century and is not expected to stop for another decade at least and perhaps much longer. Moore's Law has been the greatest driving force of technological and social change of our time.

An example of the power of Moore's Law can be seen in today's popular consumer electronics. Without Moore's Law driving newer and newer efficiencies, a simple Apple iPod music player, made with 1975 technology, would cost over $1 billion dollars.

A Moore's Law for PV?

While the fundamental laws of physics will not allow a Moore's Law for PV, there remains a critical imperative for consistent, relentless and meaningful cost per kWh reduction.

In the past decade, flat panel displays have rapidly displaced CRT technology in computers, television and other applications. Flat panel displays have grown to over a $100 billion market, up from approximately $30 billion in 2002. Thin film transistor liquid crystal display technology (TFT-LCD) is the dominant display technology and the one most similar to thin film PV technology. From to 2005 to 2010, TFT-LCD products will grow from approximately 30% to over 70% of the revenues in TVs sold worldwide. The driving force behind the rapid adoption of TFT-LCD technology has been rapid cost reduction. Unlike semiconductor technology where the learning curve is based on cost per transistor, in flat panel displays the industry learning curve is defined by cost per area. In semiconductors, the milestones in Moore's Law have been associated with new geometries: 65 nm, 45 nm, 32 nm, etc. In FPD, the cost reduction milestones have been marked with the Next Generation Substrates: Gen 3, Gen 4 … Gen 8.

The World Needs PV to be More Pervasive than Flat Panel Displays

In the semiconductor and FPD industries, Moore's Law and dramatic display achievements have been enabled by an industry structure that supports long-term growth, sustained profitability and collective response to environmental and other challenges. This supportive industry structure is characterized by a highly specialized and global supply chain of over 2,000 companies, linked together through highly publicized, industry-wide technology roadmaps, industry standards and industry trade events that accelerate technology transfer, reduce cost and facilitate innovation. The industry processes and organizing mechanisms which enable hundreds of suppliers to reach new device geometries, wafer sizes, next generation substrates, environmental standards, and other collective dependencies together—concurrently—can also be applied to the PV industry. All these characteristics and industry attributes must be nurtured and developed in the PV industry.

If we act. If we collaborate. If we learn from the past, we will create a better, more desirable future.

The decisions made today will impact the efficiency, sustainability, and profitability of the industry 10, 20, 50 years in the future. Together, we can create the perfect industry.

Join us.

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