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The photovoltaics industry: against all odds, strong growth continues

by Paula Mints

The photovoltaic industry was once, and for quite some time, the unappreciated renewable technology. Perceived as too expensive without subsidies to reduce the price of ownership, and sometimes as an energy choice primarily for environmental zealots, the industry has continued, nonetheless, to grow at a compound annual rate of 34% over the past 30 years. Growth at this rate would be envied by any industry, and certainly deserves recognition, particularly as it has come with significant problems and has been extremely difficult to achieve. Now, with worldwide consensus on global warming along with sufficient evidence that fossil fuels are rapidly depleting, solar electricity is finally earning some respect - but the industry still has perception problems to solve.

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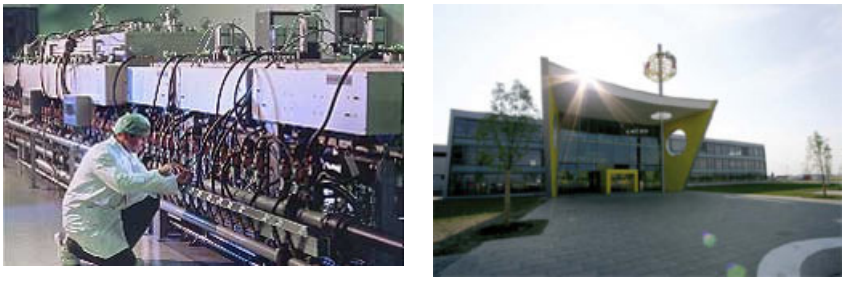


Progress in PV: On the left the CIS pilot production line of the German producer Würth Solar in 2000 (annual output approx. 1 MW), on the right the CISfab of Würth Solar opened in 2007, (capacity in 2008: 30 MWt). Source: Würth Solar

There are some who hold the view that the technology is too expensive – and, considering the price of a system to the end user (i.e., its capital cost), it is difficult to argue this point. Solar systems are expensive.

However, when the rising cost of energy and the cost of environmental damage are factored into the system price, it becomes more reasonable.

The PV industry indeed enjoys strong growth, but there are obstacles to overcome. To render systems more affordable, the PV industry continues to require incentives (direct subsidies, capacity and production rebates, feed-in tariffs and tax incentives). The industry also needs manufacturing and research subsidies and incentives, in much the same way as do all industries and technologies. In this regard, it is important to remember that all utility electricity (even that produced with fossil fuels) is subsidized at some point in its chain. Further, solar electricity is clean, renewable energy, whereas conventional energy carries a carbon cost that remains unaccounted for.

5 MW solar electric plant at Espenhain (Germany; 2004, left); 20 MW solarPV installation in Andalusia (2008). Pictures: GEOSOL, SOLPOWER AG

Growth in the PV industry

Table 1 offers the compound annual growth rates (CAGR) for the PV industry for the past 30 years, 20 years, 10 years and the last five years.

30 Year CAGR 1977 - 2007	20 Year CAGR 1987 - 2007	10 Year CAGR 1997 - 2007	5 Year CAGR 2002 - 2007
34%	27%	39%	44%

Table 1. PV industry compound annual growth rates.

In the case of PV industry growth, the CAGRs correctly indicate that the industry has experienced extraordinarily strong growth over 30 years. However, compound annual growth ignores yearly changes, and so, fails in the end to tell a complete story. Table 2 offers an insight into PV industry growth on an annual basis.

The industry saw 100% growth in 1978 over 1977, but from a very small base – 500kW in 1977 to 1MWp in 1978. In 1983, the industry grew by 88% over 1982, with growth slowing to 21% in 1984. Strong growth in 1997, the year that industry demand grew by 38% to top 100MWp for the first time, was followed by 18% growth in 1998. Since 2000, however, annual industry growth has consistently been >30%.

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
MWp	0.5	1	1.5	3.3	5.3	7.7	14.5	17.5	19.4	21	24.9
% Annual Change		100	50	120	61	45	88	21	11	8	19

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
MWp	31.5	37.9	42.7	48.2	54.1	55.7	61	71.5	82.6	114.1	134.80
% Annual Change	27	20	13	13	12	3	10	17	16	38	18

Year	1999	2000	2001	2002	2003	2004	2007	2006	2007
MWp	175.5	252	35.,9	504.9	675.3	1049.8	1407.7	1984.6	3073

%									
Annual Change	100	50	120	61	45	88	21	11	8

Table 2. PV industry annual growth rates (1977–2007).

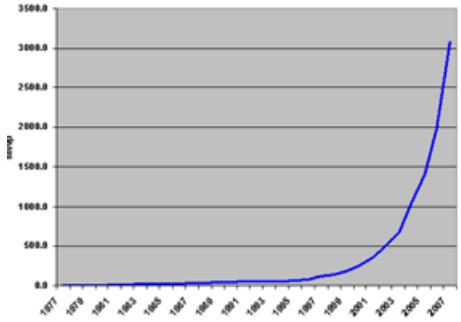
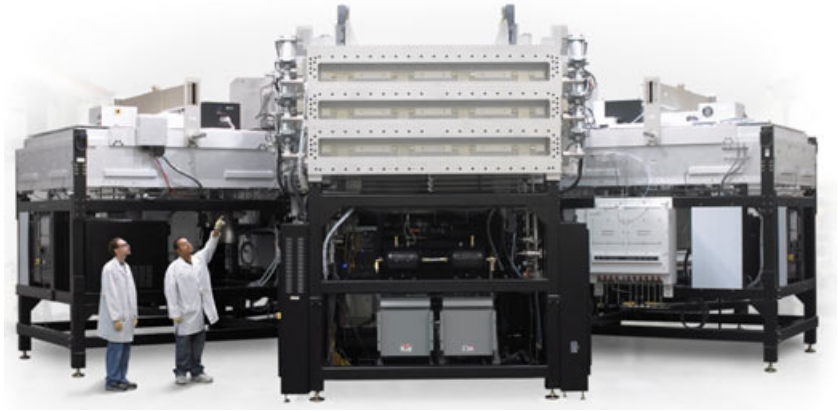


Figure 1 offers a picture of industry growth from 1977 through 2007. The industry long expected a 'hockey puck' demand curve and has achieved its aim. Despite the odds against strong growth, PV industry demand continues climbing an extremely steep upward demand curve.

Figure 1. PV industry growth (1977-2007).

Recently, the PV industry's strong growth has attracted significant investment and media attention. Much of this attention is good; the industry needs continuing R&D investment as it works on continuing technology and manufacturing developments. Industry success is also inviting professionals from other industries such as software and semiconductor to join the solar industry. New business models are emerging that remove the paradigm of buying a solar system to buy electricity. Not all electricity customers will want to own their own means of production, but, as they all understand renting electricity, it begs the question: why not rent it from a clean source? Volume and success have brought with them creative business ideas that may someday match the creativity of the technology itself.



Visible growth: PV production system by Applied Materials for plasma-enhanced chemical vapour deposition (PECVD). Source: Applied Materials.

Steep upward growth is expected to continue. Figure 2 presents a conservative and an accelerated forecast for PV industry growth from 2007 through 2012. For the conservative scenario, the CAGR for the five-year forecast is expected to be 35%. The CAGR for the accelerated forecast is expected to be 51%.

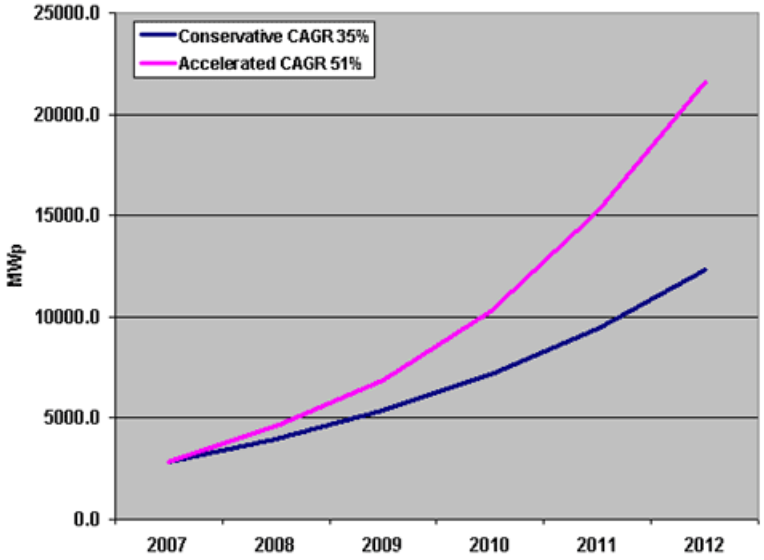


Figure 2. Conservative and accelerated PV industry forecast (2007-2012).

Since 1970, 10326.6MWp (10GW) of solar electricity has been installed globally into all applications and for all customer types. Ninety percent of this was installed from 2000 to 2007, and 73% was installed from 2004 to 2007. The situation in 2004 saw most technology manufacturers break even for the first time, and in some cases, make profit for the first time. The terrestrial PV industry is more than 30 years old, and has been profitable for about four years. Europe and its mighty feed-in tariff is the driving force behind the industry's success.

The role of incentives and the future of solar electricity

There is no doubt that the feed-in tariff model, which provides a pure economic incentive to buy a solar system, has proven to be the most successful market stimulus for the PV industry. Japan's capacity-based incentive stimulated a strong market until its cessation, but Germany's feed-in tariff kick-started industry demand, resulting in unexpected volumes of demand. The feed-in tariff incentive model, in its pure (and currently changing) form, allows the system owner (or system investors) to profit from ownership in what amounts to a two-year annuity payment.

From 2002 through 2007, Germany experienced a phenomenal 61% compound annual growth in demand for PV products. Without a doubt, it can be said that in 2004, 2005, 2006 and 2007, demand in Germany drove the global market for PV products. Other countries in Europe have patterned programs on the German model. At this juncture in PV industry history, Europe represents more than 70% of total industry demand. Figure 3 presents regional PV industry growth from 2002 through 2007.

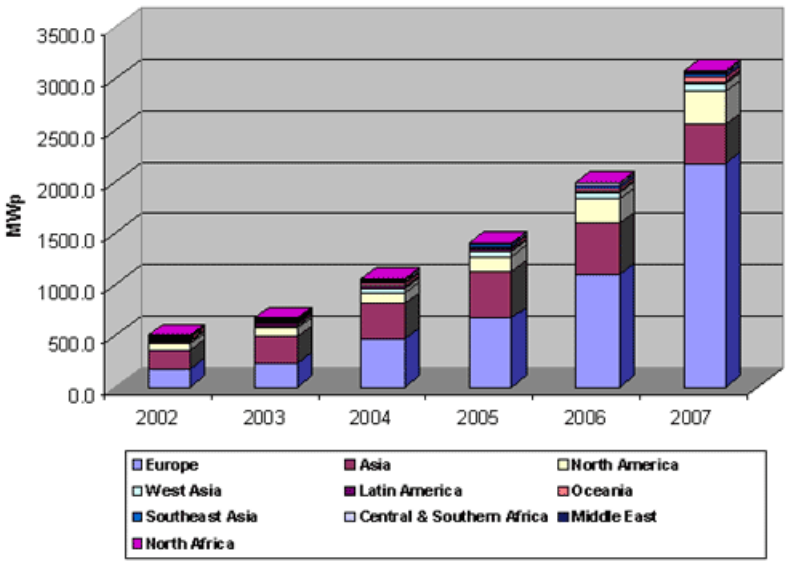


Figure 3. Regional PV industry growth (2002-2007).

Europe's successful feed-in tariff programs are expensive, and need controls to render them manageable. Otherwise, the very programs that are stimulating demand threaten to become too expensive to continue in the long term. In this regard, Spain is a perfect example. Spain is the strongest global market in 2008, but its program was revised this September and the government is implemented an annual cap. Given that demand in Spain for 2008 is ~1500MWp, a 500MWp cap for 2009 and beyond appears like a blow to the industry. Regardless, Europe will continue to be the strongest global market for solar products for quite a few years.

At this point in U.S. PV market development, incentive programs, net metering and clear interconnection standards are necessary for the U.S. grid-connected market to thrive and, frankly, to survive. These programs (and in particular, the federal tax incentive) are also necessary for the power purchase agreement model (PPA) to function profitably and at lower risk for investors. Programs must be put in place to help build an economically sustainable PV market, while enabling the manufacturing sector to develop needed efficiencies and cost-cutting techniques. In the future, the net-metering penalty (whereby the system owner is not permitted to profit from the excess electricity fed into the grid, but can only zero out an electricity bill) needs to be changed to encourage larger systems, and more system ownership. Incentives for manufacturing must also be put in place to strengthen the U.S. manufacturing sector. Finally, the utility exemption must be amended or repealed to allow investor-owned utilities (IOUs) and publicly-owned utilities (POUs) to take advantage of the federal tax incentive.

Left: 23 MW solar energy system in Spain; right: 15 MW solar PV installation at Nellis Air Force Base (Nevada). Sources: Munich Energy Partners; U.S. Air Force

The future of renewable energy credits (RECs) as a system-financing tool in the U.S. cannot be ignored. Renewable energy credits can function on their own or as a compliance tool. They are more lucrative as a compliance tool, operating in that regard almost as a performance incentive. As RECs become more common, their usefulness in the incentive mix will become more apparent. At some point, a state could use RECs to fund its rebates. Many investment groups, some of whom are hoping to profit from a future market for selling solar-generated electricity, are counting on an explosive REC market to help drive profits. However, there is no consistent system in place in the U.S. towards the use of RECs and use of this vehicle remains in the formative stages.

In Japan, the cessation of that country's subsidy program has slowed the market considerably, and the government is considering a new incentive scheme to restart demand.

The market in South Korea is emerging, but remains beset with bureaucratic problems that slow sales of systems to that country. Recent changes to the country's feed-in tariff may limit demand. After October 2008, the feed-in rates change significantly, and in 2012, the country's solar incentive switches to an RPS (renewable portfolio standard)-driven plan that currently does not favour solar electricity. One likely reason for the changes through 2009, the lag, and then the significant change to RPS focus in 2012 is that system and component prices have risen instead of falling. Markets with high demand will tend to drive up prices, a problem for an industry with downward price pressure from governments.


Left: 70 kW PV roof in Yachiyo Ciy (Japan). Right: 19,6 MW PV power plant at SinAn (South Korea). Sources: Evergreen Solar, Inc. Conergy AGLeft: 70 kW PV roof in Yachiyo Ciy (Japan). Right: 19,6 MW PV power plant at SinAn (South Korea) Sources: Evergreen Solar, Inc. Conergy AG.

China and India have strong potential to emerge as significant markets, but have yet to exercise this potential because solar electric technologies remain expensive to implement, coal is cheap, and both countries have affordability problems.

Solar modules – where are they going?

Solar modules are eventually installed in systems. Systems, however, are sold into applications, to regions, to countries and to end users within all of these sectors. Table 3 provides a brief overview of the applications.

Market Category	Status – Valuation – Reliability	Customer Description
Remote Industrial	- Earliest commercial market - High credit for economic value - Reliability required: high - urgent	- Most sophisticated customer - Requires detailed specifications but lesser systems support
Remote Habitation	- Second market entered in volume - Medium value and reliability - PV is life-cycle-competitive now	- Least sophisticated customer, in developing countries - Most systems support required

Consumer Power	- Established niche markets - Novelty, portability, and independence from conventional power are key	- More sophisticated customer in industrialized countries- Little customer support required
Grid-Connected	- Market penetration continuing, driven by incentive and investment models - Gaining credit for economic value - System reliability required: high - Lifetime required: long	- Industrial country consumer - Education needed to raise perception of value - Ongoing support structure required - Beginning of interest from building industry - New investment models changing paradigm from owning means of producing electricity back to renting electricity from an independent source
Consumer Indoor	- 1980s – market entry and saturation - Economic value: non-issue - Reliability, life required: low	- Broad, global customer base - Little customer support required - Short lifetime expected

Table 3. Photovoltaic application segment overview.

More than 70% of solar modules go to Europe. In the near term, this will continue to be the case. Other markets, including the U.S. market, are still emerging, and will take time to do so. The market in Japan needs to re-emerge. The remainder of solar product goes into the grid-connected application. In 2007, 90% of demand was for grid-connected products. In the near term, this too will continue to be the case. The pie charts in Figure 4 provide an overview of global demand in 2007, by application and by region.

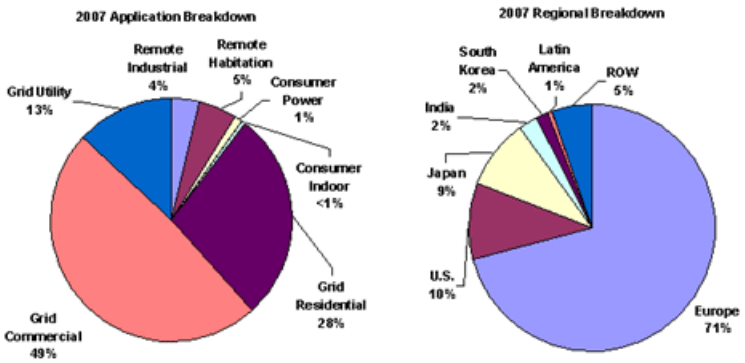


Figure 4. Global demand 2007 – breakdown by region and application (total demand in 2007 was 3073.0MWp).

The industrialized and developing world markets for photovoltaic products require financing mechanisms to ensure current and future market growth. In the developing world, unstable economies, poverty, and lack of credit (among other problems) continue to dampen growth prospects. Photovoltaic products are still primarily used for off-grid applications in developing countries, though there is new interest in extending the grid (where possible) to some rural communities. In industrialized countries, subsidies and incentives for the grid-connected application are the primary drivers.


Installation of a off-grid PV system in Tanzania. Solar PV modules for rural electrification by SCHOTT in Indonesia. Pictures: Energiebau Solarstromsysteme GmbH; SCHOTT Solar

In developing countries, the need for photovoltaic technologies to provide electricity to remote houses and villages is great, while the ability of remote populations to afford the technology remains poor. Problems with supplying these remote areas with PV systems include the inability to afford a system, lack of credit, lack of maintenance, poor or no training, theft, poor administration, and difficulties working with governments. In urban areas of developing countries, conventional utility electricity is often priced below the cost of production, providing an effective barrier to grid-connected PV technologies. One of the biggest problems confronting suppliers of PV to the developing world remains the difficulty of coordinating and working with different government departments. Other problems include graft, lack of a local PV industry, and taxes that increase the difficulty of selling to developing countries (rendering the price of the product beyond local affordability). The current shortage of raw material has recently made sales to the developing world unattractive to manufacturers of product.

At this point, the international solar industry continues to celebrate its strong success and extraordinary growth, while at the same time anxiously looking for the next strong market. As long as this growth remains subsidy-driven, it is also artificial. The industry must continue to lower costs, while convincing all participants along the value chain to lower margins and profits so that a sustainable (long-term) market can emerge.

The grid residential application experienced extremely strong compound annual growth from 1997 onwards. During this time, the original German program, along with Japan and California, were strong drivers for residential system installation. Growth in the grid-residential application slowed in the 2002-2007 period, to a CAGR of 24%. During the forecast period, the residential sub-application is expected to experience strong growth of 36% to 52%, with the high forecast achieved through the development of new business models.

Driven by feed-in tariff laws in Europe, and the PPA model in the U.S., the grid-commercial application (specifically, installations >1MWp) will continue to experience strong growth. From 1997 to 2002, the grid commercial application grew at a compound annual rate of 36%. From 2002 through 2007, the grid-commercial application grew at a compound annual rate of 116%. For the forecast period, the sub-application is expected to grow at a CAGR of 32% to 48%, with closer to the latter figure assumed.


PV generator(3 kWp) on the roof of a garage in California; aerial photo of the 2 MW solar power plant at Fort Carson. Sources: Evergreen Solar, Inc.; Conergy AG

The model under which utilities purchase solar, particularly in the U.S., is changing. RPS standards in the U.S. and strong growth in Spain are factors driving strong growth in the grid-utility application. In the U.S. RPS, standards with solar set-asides require utilities to produce a percentage of electricity from solar sources. For utilities, it is the cost of the components, not the price of a system, that is the important buying factor. However, some utilities in U.S. states without the RPS requirement are showing interest in PPA installations. A steady decrease in the cost of solar components could encourage stronger use by utilities. The grid-utility application grew at a compound annual rate of 22% for the 1997 to 2002 period. The sub-application experienced compound annual growth of 110% from 2002 to 2007 because of strong growth in 2007, primarily into Spain. In 2007, over 2006, the grid-utility application grew by 1642%. For the forecast period, the sub-application is expected to continue at strong compound annual growth of 42% to 59%.

The grid-connected application is the largest and fastest growing of all of the photovoltaic market segments, with an 80% share of global volume in 2004, an 82% share in 2005, an 86% share of total volume in 2006, and a 90% share of total volume in 2007. Clearly, this incentive-driven trend is here to stay. The fastest growing sub-segment of this application is large (>1MWp) field and roof installations.

Table 4 provides a history of grid-connected application growth and clearly illustrates that success for the grid-connected application has not been easy, nor has it been seamless. In the beginning, the majority of grid-connected installations were government or utility demonstrations with no real commitment to investing in the technology. In 1983, a year of several demonstration projects, the application grew by 213% over the previous year, had a 50% share, for a total of 7.5MWp installed. In 1984, growth declined by 21% and the application had a 34% share. In 1990, the application grew by 200% over the previous year, and had an 8% share of total application sales (meaning that off-grid applications had a 92% share). In 1995, growth into the grid-connected application declined by 22% after growing by 197% the previous year.
In 2000, the grid-connected application grew by 87% and had a 51% share of application sales, a trend that has continued leading to the >90% share that the application enjoys in 2008.

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Grid-connected MWp	2,4	7.5	5.9	4.1	1.7	1	1.6	1.1	3.3	3.9	3.8
% Yearly Change	55	213	-21	-30	-59	-41	-58	-28	200	18	-2
% Total Demand	31	50	34	22	8	4	5	3	8	8	7

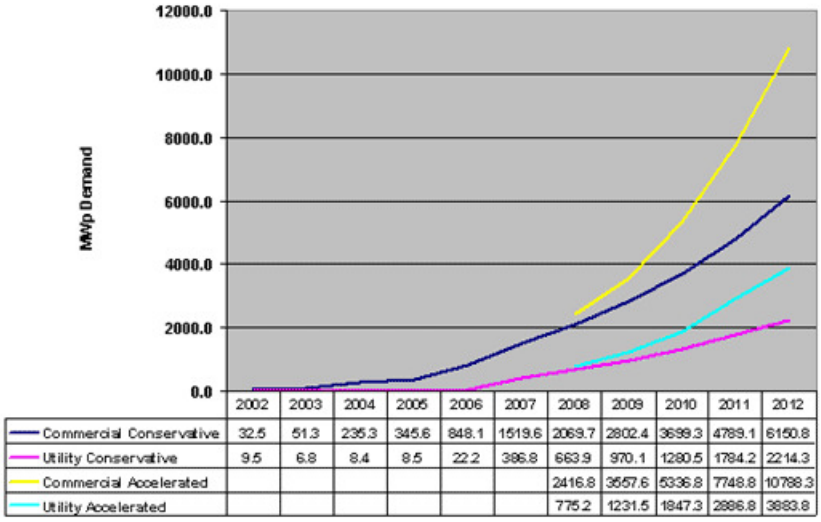
Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Grid-connected MWp	3.9	11.6	9	1.,6	38.3	41.8	68.4	128.2	209.7	338.3	484.2
% Yearly Change	3	197	-22	28	235	8	64	87	64	61	43

% Total Demand	7	19	13	14	34	31	39	51	59	67	72

Year	2004	2005	2006	2007
Grid-connected MWp	838.2	1161.2	1707.2	2762.9
% Yearly Change	72	40	47	62
% Total Demand	80	82	86	90

Table 4. Grid-connected yearly application growth and percentage of total demand (1982-2007).

The current trend is to large-field or utility-scale applications where an investor group installs >1MWp of PV, and sells the electricity to an end user, or end users. This trend is expected to continue to dominate application sales. Figure 5 observes growth into the commercial and utility grid-connected applications from 2007 through 2012. Business models that do not require system ownership have accelerated the already strong growth rate of the grid-commercial application, and stimulated the utility-grid application.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Commercial Conservative	32.5	51.3	235.3	345.6	848.1	1519.6	2069.7	2802.4	3699.3	4789.1	6150.8
Utility Conservative	9.5	6.8	8.4	8.5	22.2	386.8	663.9	970.1	1280.5	1784.2	2214.3
Commercial Accelerated							2416.8	3557.6	5336.8	7748.8	10788.3
Utility Accelerated							775.2	1231.5	1847.3	2886.8	3883.8

Figure 5. Grid-connected application forecast (2002-2012).

The remote applications (habitation, industrial, consumer power) are cost effective without subsidies – and have been for years. For remote applications, though affordability is still an issue, the cost - or simply the possibility - of extending the grid to remote populations far outweighs the cost of the PV system. This does not mean that affordability is not an issue; simply that conventional utility electricity may not be possible.
For many years, the PV industry was dominated by the remote application. Table 5 provides data on application trends from 1992 to 2007. In 1992, grid-connected applications were 7% of total demand. By 1997, grid-connected applications were 34% of total demand, and now make up 90% of global demand.

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total MWp Worldwide	54.1	55.7	61	71.5	82.6	114.1	134.8	175.5	252	352.9	505
Off-Grid % Total	88	88	76	82	81	62	65	58	47	40	30
Grid-Connected % Total	7	7	19	13	14	34	31	39	51	58	67
Consumer Indoor % Total	5	5	5	5	5	4	4	3	2	2	2

Year	2003	2004	2005	2006	2007
Total MWp Worldwide	675.4	1049.8	1407.7	1984.6	3073
Off-Grid % Total	27	19	17	14	10

Grid-Connected % Total	72	80	82	86	90
Consumer Indoor % Total	1	1	1	< 1	< 1

Table 5. Application trends (1992-2007).

Conclusion

The PV industry remains beset by many obstacles: the continuing (expensive) need to invest in R&D, the need to reduce manufacturing costs and increase efficiency (common issues for thin-film and crystalline technologies), downward price pressure forced upon the industry by its need for incentives, constant anxiety that incentives will end before sustainable demand is obtained, too little capacity to meet demand, too much capacity and, as a result, under utilization, competition from other energy sources and most difficult of all, higher expectations that the industry needs to meet.

In recent years, the current high volume of industry demand, coupled with raw material shortages, presented a new challenge to the industry. Unfortunately, with a significant amount of new capacity coming on line in the next few years, there may be a fresh set of obstacles to be overcome.

The industry faces many challenges, coupled with a wealth of success stories to prepare it for the battle. And with the world now viewing solar as a mainstream energy choice, this battle is almost won. The energy future is a renewable one, and it is looking as if solar electricity will be a major part of that future.

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Paula Mints is the Principal Analyst for the PV Service Market Research Program, and an Associate Director at Navigant Consulting, Inc. She also serves as primary author and executive editor of the Solar Outlook Quarterly Newsletter, and is a member of the European Union WG3 PV Technology Platform. A widely recognized industry expert on PV technologies and markets, she has been published in several industry journals and is in demand as a speaker on the industry at global events. She has a B.S. degree in business concentration and an M.B.A. in market research focus, both from San Jose State University.

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