

Status of PV Research, Solar Cell Production and Market Implementation in Japan, USA and the European Union



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Front cover: Amorphous Silicon Facade on the ELSA Building at the JRC Ispra, Italy
picture by: Jennifer Rundle

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PREFACE

The search for a substitute for fossil energy sources, the world-wide improving environmental awareness and the needs of the growing population in developing countries have increased the interest in photovoltaics as a long-term, inexhaustable, environmentally friendly and reliable energy technology. In the last five years, the production of photovoltaic cells has increased steadily by an average of 30% per year, driven not only by the progress in materials and processing technology, but by market introduction programmes in many countries of the world. This leads to the search for new developments with respect to material use and consumption, device design and production technologies as well as new concepts to increase the overall efficiency.

At present solar cell manufacturing based on the technology of crystalline, single junction devices is growing by approx. 30% per year and this growth rate is increasing. Consistent with the time needed for any major change in the energy infrastructure, another 20 to 30 years of sustained and aggressive growth will be required for photovoltaics to substitute a significant share of the conventional energy sources. This growth will be possible if a continuous introduction of new technologies takes place, made possible by sound fundamental research.

The rising number of market implementation programmes in Japan and the European as well as the different regional incentive programmes in the US, contribute to increase the demand for solar systems. In the long-term the growth rates for photovoltaics will continue to be high, even if the economic frame conditions can lead to a short-term slow down of the growth rates. This report tries to give an overview about the current activities in Japan, the US and Europe regarding Research, Manufacturing and Market Implementation. The opinion given in this report is based on the current information available to the author, and do not reflect the opinion of the European Commission.

This report is based on visits to Japan and the US in the spring of 2002, where government entities, research centres and the leading industry companies were visited. I would like to thank all my hosts for their kindness and the time they took to receive me, to share their knowledge and to discuss about the status and prospects of photovoltaics.

Ispra, September 2002

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1. INTRODUCTION

In 2001, the photovoltaic industry delivered world-wide some 396 MWp [1] of photovoltaic generators (Fig. 1) and has become a 2.5 bill. \$ business. In the past 5 years, the yearly growth rate was an average of 30%, making further increase of production facilities an attractive investment for industry. As about 85% of the current production involves crystalline silicon technology, scale-up of production capacity for this technology will be required in the same proportion. This is a well-established market, which achieves sufficient efficiency for at least 20 years of lifetime and constitutes a low-risk investment with high expectations for return on investments. Should growth in this technology continue as in the past years, the supply of cost-effective silicon feedstock might limit the achievable cost reduction, especially if feedstock costs cannot be kept below about 0.50 €/Wp.

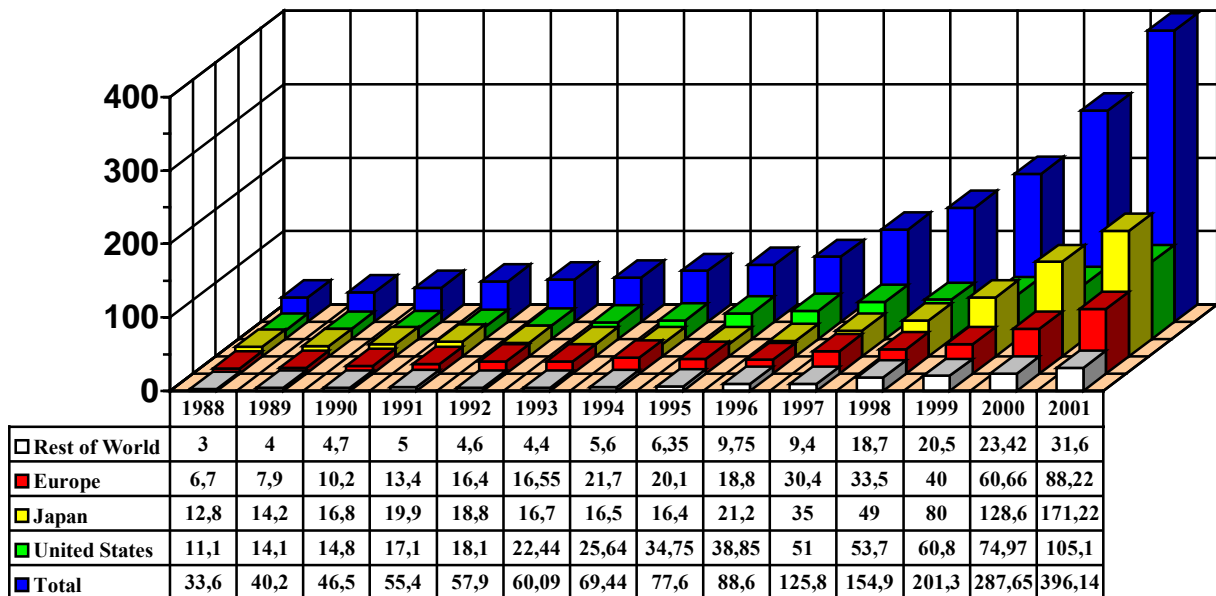


Fig. 1: World PV Cell/Module Production from 1988 to 2001 (data from PV News [1])

Similar to learning curves in other technology areas, a second generation of devices will steadily increase its market share, until the previous, first technology will be replaced. This 2nd generation technology, after years of research and technology - and also lawsuits - is readily available and just on transition from pilot to industrial production. Equally competitive technologies are amorphous Silicon, CdTe and CI(G)Se. This growth of these second generation technologies will be accelerated by the positive development of the PV market as a whole and there are many indications that the required scale-up to manufacturing units of 50 MWp yearly capacity will soon join 1st generation silicon devices in satisfying demand. However, the growth of thin film production capacity within this decade must be at least 40%

to achieve a market share of 50% in the photovoltaic production of 2010, assuming that total PV growth continues at a constant 27% per year. By then, Silicon technology would deliver about 1.500 MWp per year, requiring probably 12,000 metric tons of Si-feedstock, about half of today's entire Silicon world production, and one can speculate that thin-film technology will continue to grow even faster. Further cost reduction will depend not only on the scale-up benefits, but also on the cost of the encapsulation system, as efficiency will remain limited below 15%, stimulating strong demand for very low area-proportional costs.

2. THE WORLD MARKET

Figure 1 shows the development of the sale figures from 1988 to 2001. Besides the exponential increase of the world market, which led to a rising interest of institutional investors [2], there is the rapid increase of the Japanese production capacities of particular interest. Within 8 years from 1994 to 2002 Japan has propelled itself to the position of a world market leader both in supply and demand of solar cells (Fig. 2). The situation is even more impressive if one takes into account the increase of production capacities announced (Fig. 3). Compared to their US and European competitors the Japanese photovoltaic companies have fulfilled what they announced with remarkable reliability concerning the time frame. One remarkable example is the Sharp Corporation.

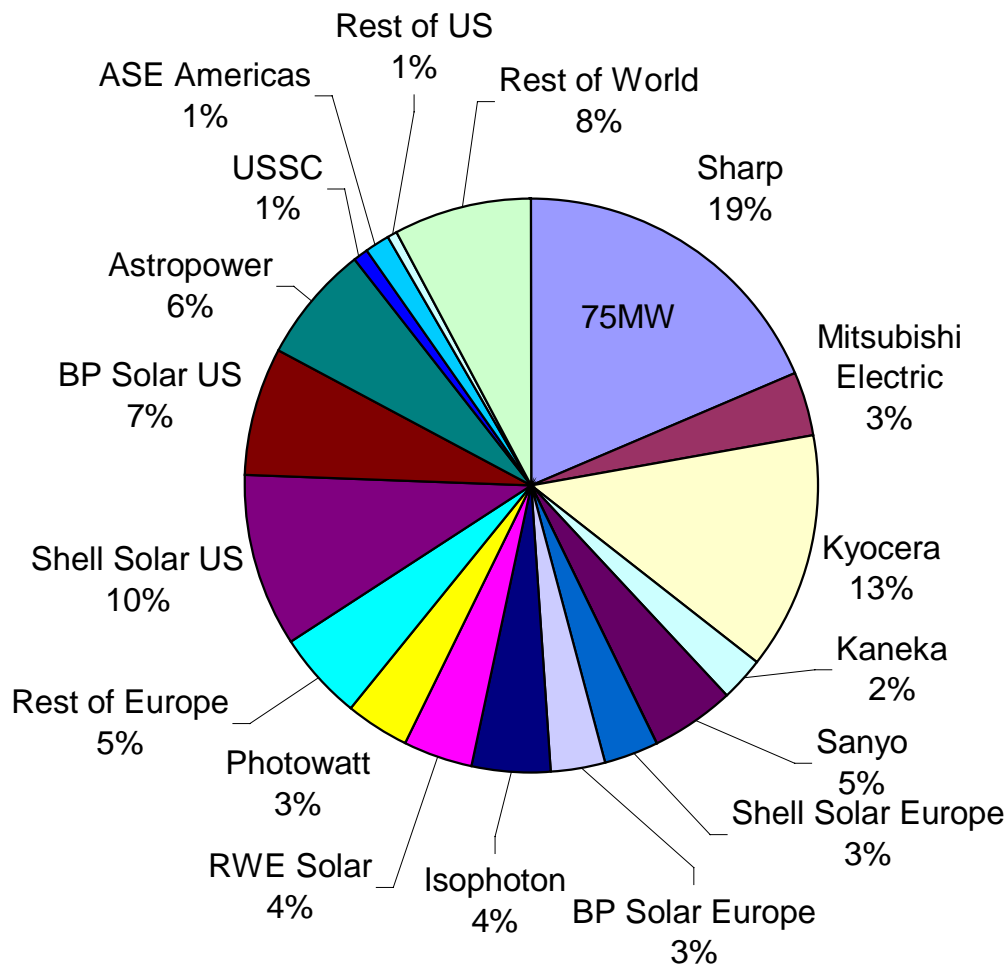


Fig. 2: World-wide sales of solar cells 2001 (396 MW) [1]

On 20 June 1997, Sharp released the following press release [3]: “In response to a rapidly increasing demand for solar cells at home and abroad, Sharp Corporation will build Plant No. 3 of Electronic Components Group, a solar cell plant of world-class scale and capacity, in Shinjo-cho, Kita-Katsuragi-gun, Nara prefecture. The initial production capacity will be 20

MW in fiscal 1998¹ (FY1998), and can be expanded to a maximum of 150 MW, depending on demand trends.” When the Business Plan for 2002 [4] was presented on 1 February 2002 an expansion to 200 MW was announced for the end of FY2002. In order to promote further business expansion, the Solar Systems Division was separated from the Electronic Components Group and the new Solar Systems Group was created in January 2002.

The press release of 1997 was received with caution due to the fact that at that point Sharp had only a production capacity of 5 to 10 MW/year and held only approx. 6% of the world market share. However, in 2001 Sharp had sales of over 75 MW and had become the world market leader with 19% market share. According to a Sharp press release of 23 July 2002 [5] their production capacity had reached 148 MW and with that accomplished the target set in 1997. In addition, the other four Japanese solar cell producers plan significant increases of production capacities as well.

Compared to this impressive increase, the planned expansion of production capacity in Europe is rather moderate. The time frame for the increase announced by RWE-Solar [6] and BP-Solar [7] to 60 MW annual production each in Europe stretches to 2004/5. The only exemptions are the Spanish solar cell producer Isofoton who has outperformed the other European manufacturers so far and the newcomer Deutsche Cell GmbH [8]. Deutsche Cell has reported the opening of its new 30 MW plant in Freiberg in September 2002 and plans to increase the capacity to 60 MW by 2004/5.

With growth rates above average, Isophoton has become the largest manufacturer of solar cells in Europe (18 MW in 2001) [1]. This development is even more surprising as Isophoton has no strong mother company as a back-up. The production capacities are planned to reach 35 MW in 2002 and double to 70 MW by 2004 [9].

It has to be noted that the assessment of all the capacity increases is rather difficult and is affected by the following uncertainties:

- The announcement about the increase in production capacity in Europe and the US often lack the information about completion time compared to Japan. Due to the Japanese attitude that a public announcement reflects a commitment, the pressure to meet a given time target is higher in Japan than in the US or Europe where delays are more acceptable.
- The announcement of completion of the capacity increase very often only refers to the installation of the equipment. It does not mean that the production line is really fully operational. This means, especially with new technologies, that there can be some time delay between the installation of the production line and real sales of solar cells.
- Available production capacities are not equal to sales, therefore there is always a noticeable difference between the two figures which cannot be avoided.

¹ Japanese financial year (FY): 1 April to 30 March

Therefore, only limited comparisons between the US, Japan and Europe are possible. Despite the fact that in actual sales, Europe will surpass the US in 2002, the overall difference between Europe and Japan has become even larger. This development is of particular interest in view of the strategic importance of solar cell production for the electrification of developing countries as well as the fulfilment of the Kyoto Targets.

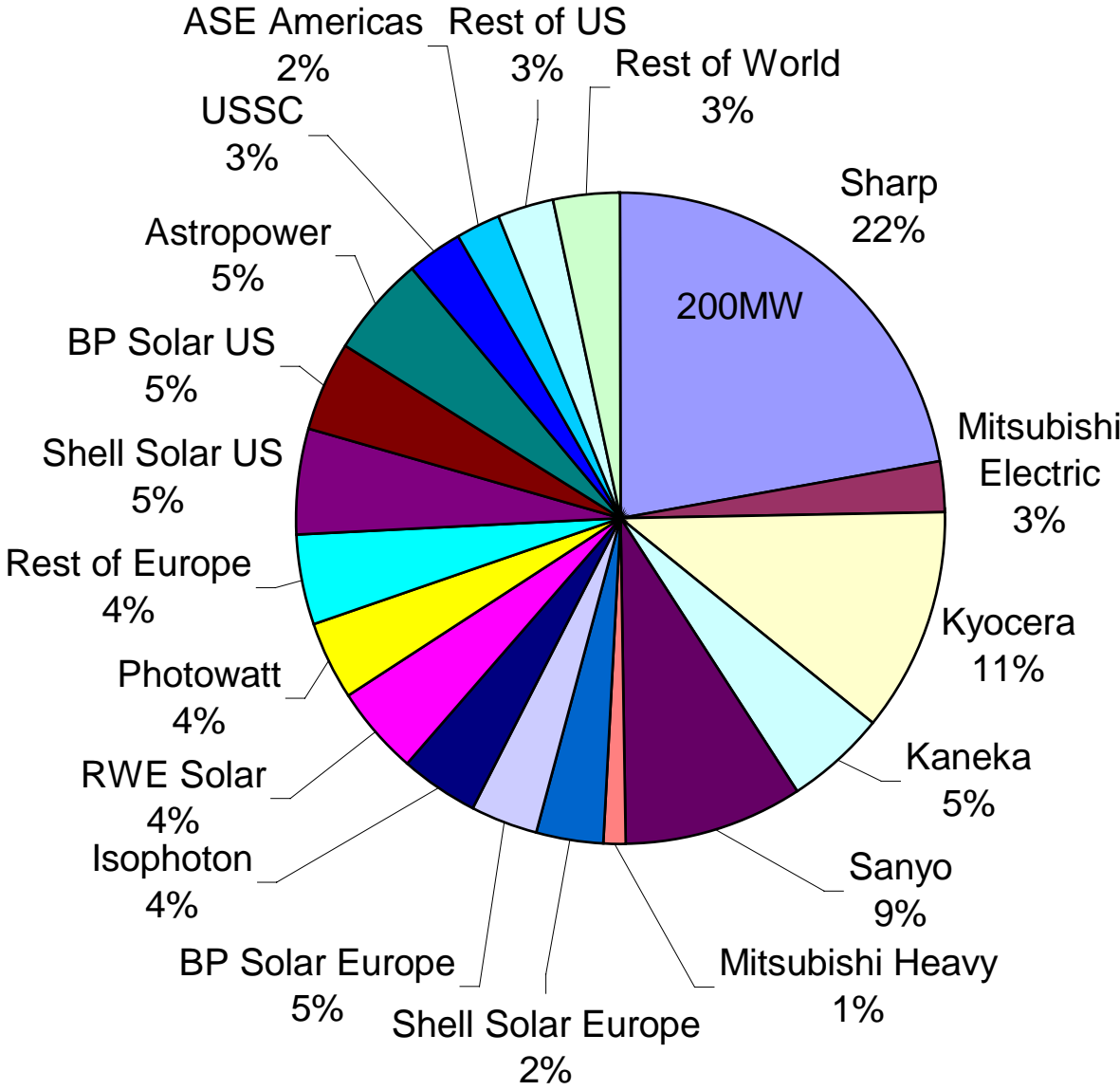


Fig. 3: Announced increase of production capacities world-wide by the end of 2002 (900 MWp)

3. PV IN JAPAN

The Japanese PV research and development programmes, as well the measures for market implementation, have ensured within the last 10 years that Japan has become the leading PV nation world-wide both on the supply as well as on the demand side. The main reasons for the METI to support renewable energies are:

- Security of Japanese energy supply
- Fulfilment of the pledged Kyoto Targets.

3.1 Introducing New Energies

The reasons and necessities for introducing new energy resources in Japan differ from those in Europe and are worthwhile taking a closer look.

The basic goals of the Japanese activities for the introduction of ‘New Energy’ as a national energy supply were laid down in the 1993 New Sunshine Project a follow up of the Sunshine Project started 1974, under the impression of the first oil crisis. The ‘Basic Guidelines for New Energy Introduction’ were set by the ‘Council of Ministers for the Promotion of Comprehensive Energy Measures’ in December 1994 and were based on a Cabinet Decision in September 1994. In the framework of the ‘New Sunshine Project – 1st Stage’, which ended in March 2001, photovoltaics was one of the ‘New Energies’ under investigation. In Japan, the term ‘New Energy’ includes besides renewable energies such as biomass, solar thermal, photovoltaics and wind energy also the innovative use of fossil fuels, e.g. cogeneration, fuel cells, etc. and recycled fuel energy like waste power generation, etc.

This highly successful programme underwent a basic review in 2000, which led to the outline of the New PV Technology Programme called “Advanced PV Generation” (APVG). Due to the administrative reform of the Japanese governmental structure, the New Energy Development Organisation (NEDO) now has a new structure (independent governmental entity) and a new role in the execution of the photovoltaic programme. The New Sunshine Project Headquarters was abandoned at the end of FY 2000, and taking effect in FY 2001, NEDO replaced the New Sunshine Project by the “Advanced PV Generation” programme. As a result of the New Sunshine Project (NSP or NSS) evaluation, several important priorities were selected.

The first topic mentioned in the ‘Basic Guidelines’ is to decrease the almost 100% dependence on petroleum imports, which account for approx. 53% of the primary energy consumption in Japan. After the first oil crisis, this was a primary issue in Europe as well, but now with the exploitation of the North Sea oil and gas fields it has currently not the same importance.

Second, the commitment of Japan under the Kyoto Protocol to reduce its heat-trapping gas emissions by 6% from 2008 to 2012, compared to the 1990 level, is another argument for the

accelerated introduction of new energies. It was intended to reach this aim with the introduction of new energies, energy savings and the increase of nuclear power generation. So far this mixture seemed to be in agreement with the national energy consensus. However, after the last few problems with nuclear facilities, it looks like that this consensus is fading, due to increasing opposition to nuclear power and the linked safety and storage problems.

On 14 March 2002, Kyodo News reported about the new draft guidelines to achieve the greenhouse-gas emissions reduction by a "policy mix" approach, which combines voluntary efforts by industry, with mandatory restrictions and market-based approaches. These new guidelines suggest for the first time, that Japan should study introducing an environment tax and market-based methods. The revision of the guidelines originally set in June 1998 became necessary because the total amount of greenhouse-gas emissions in Japan rose 6.8% from the 1990 levels in fiscal 1999, and in 2010 the amount is expected to stay at 7.4% above the 1990 figures. In such an event, Japan would be obliged to cut greenhouse-gas emissions by 13.4%. The new formula presents 45 fresh approaches to achieve the goal, including further promotion of renewable energy, such as solar and wind power and energy-saving measures like the introduction of daylight-saving time. The document shows that Japan will aim to achieve 2 percentage points of the 6% reduction through "development of innovative technology and citizens' efforts."

Another reason for the introduction of new energies is stipulated in the "Basic Guidelines" chapter about photovoltaics: *'The international market'*. This is a fundamental difference in the attitude of implementing renewables between Japan and Europe. The Japanese policy has not only the advantage to be much more market oriented, but also has a major aim in the policy guidelines: *'The establishment of a prospering market'*. These expectations are also expressed by the long-term goals, which already in 1994 made a commitment for the next fifteen years until the year 2010. This long-term policy and commitments are a huge advantage as can already been seen, as industry can rely on such a long-term programme and plan their individual industry policy as well. Hitherto, in Europe the national as well as the European Community programmes are clearly lacking these long-term policy commitments!

At the beginning of the programme, the critics said that the set goals are just mere visions and will not be fulfilled due to the very high targets set in the plans. However, currently the target for 2000 to install 400 MWp in Japan was met with only one year's delay and the present developments of production capacities and market growth indicate that the target of 4.8 GWp in 2010 can be met as well. This shows that the attempt to promote new technologies with visions of future developments is creative, competitive and successful. Figure 4 and Table 1 show the increase of PV roof-top installation since 1997 [10].

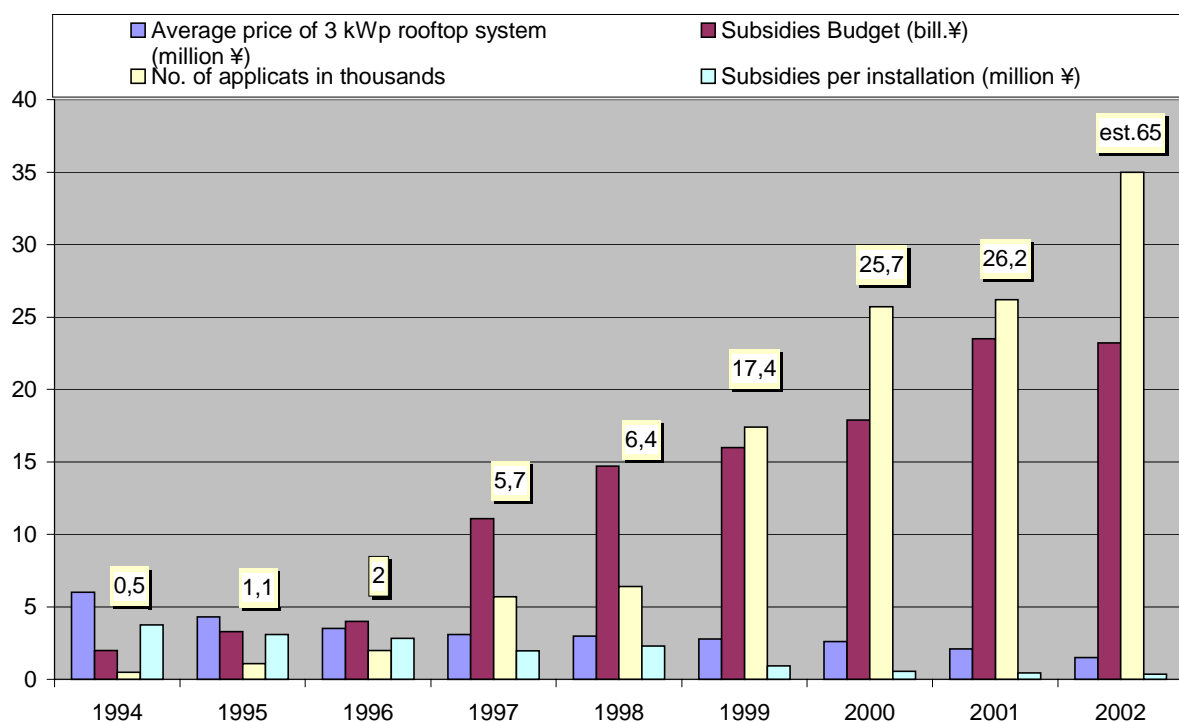


Fig. 4: Increase of PV roof-top installation

Tab. 1: Development of PV roof top systems

Year	Average price for 3 kWp system [mill. ¥]	Budget [bill. ¥]	Systems [in 1000]	Subsidy per system [mill. ¥]
1994	6,0	2,0	0,5	3,76
1995	4,3	3,3	1,1	3,10
1996	3,5	4,0	2,0	2,81
1997	3,1	11,1	5,7	1,96
1998	3,0	14,7	6,4	2,31
1999	2,8	16,0	17,4	0,92
2000	2,6	17,9	25,7	0,56
2001	2,1	23,5	26,2	0,44
2002	est. 1,5	23,2	est. 65 ²	0,35

When looking at these PV installation figures one has to bear in mind that they do not include PV installations by public organisations or industry. It can be observed that despite the relatively low level of METI subsidies, there is a high potential for PV in Japan. An additional

² On 6 September 2002, 15 900 applications were already registered for FY2002

incentive is the “net-metering” of the electricity produced. The average electricity prices in Japan are 24 ¥/kWh for residential use and 10 – 12 ¥/kWh for industrial use.

3.2 History of Renewable Energy Introduction

The first programme to stimulate the implementation of PV in Japan was called “Monitoring Programme for Residential PV systems” from 94 to 96 and managed by the New Energy Foundation (NEF). Within this programme, 50% of the installation costs were subsidised. This led to a cost reduction from 2 million ¥/kWp in 1994 to 1.2 million ¥/kWp in 1996. The annual budget was relatively modest, increasing from 2 billion ¥ in 1994 to 4.06 billion ¥ in 1996. The number of installations per year increased from 539 to 1986 during this time. In 1997 the “Programme for the Development of the Infrastructure for the Introduction of Residual PV Systems” was launched with a massive increase in funds. From 1997 to 2001, the funds increased from 11.11 billion ¥ to 23.5 billion ¥. During the same time, the subsidy decreased from 340 000 ¥/kWp to 120 000 ¥/kWp and the average system price decreased from approx. 1 million ¥/kWp to 750 000 ¥/kWp. The price target set for the future ranges between 300 000 and 500 000 ¥/kWp and should be realised with the help of increased production (learning curve) and PV integration into the buildings.

In addition to this subsidy, handled by NEF, some local governments (136 additional local subsidising bodies) add additional funds of up to a maximum of 40% of the total costs for the installation of systems. The number of 136 local governments seems high, but one has to remember that Japan has approx. 3 700 local governments (Prefectures, Cities, Townships etc.). It can be observed that those Prefectures which give additional subsidies have significantly more PV installations than the others (Aichi 12 812 MWp, Hyogo 11 319 MWp, Nagano 10 866 MWp; vs. Akita 703 kWp, Shimane 697 kWp, Fukui 447 kWp). The average residential PV system has 3.5 to 3.7 kWp. This size correlates with the upper limit of 4 kWp per system to receive subsidies from central and local governments. The METI subsidy programme is scheduled to finish at the end of FY 2002, but the general consensus is that it should be continued, even if the subsidy percentage will be lowered even more.

Driving forces for the residents to install PV systems are a growing environmental awareness in the light of the Kyoto protocol, the subsidies offered as well as the net-metering of the generated electricity. The electricity production averages 950 kWh/kWp year in Japan and even the snow-rich west coast along the Japanese Sea, the so-called Snow-Land, averages 850 kWh/kWp year. This means that the average annual electricity savings are approximately 23 400 ¥/kWp and 21 000 ¥/kWp respectively. Due to these programmes, the PV power accumulated in Japan has reached 441 MWp by the end of FY 2001 with 309 MWp installed as residential PV systems.

The average residential PV system in Japan had 3.6 kWp (2001) and was priced at an average of 820.000¥ per kWp. The subsidy for residential PV systems in FY 2001 was

120.000¥, but it will be lowered in FY 2002 to 100.000¥. The allocated budget in FY 2001 was 23.51 billion ¥ (200.94 million €)³ and will stay roughly at the same level for FY 2002 (23.20 billion ¥; 198.29 million €). This budget would have been sufficient for the installation of 196 MWp for FY (approximately 50.000 PV residential units) and 232 MWp for FY 2002. However, due to the economic slowdown, the residential PV installations will be “only” 120 to 130 MWp in FY 2001. The tight economic frame conditions and budgetary restraints are currently a challenge for the continuation of this subsidy scheme in 2003. However, there are good chances for the continuation of this programme because, it is viewed by the Finance Ministry as one of the few really successful market implementation programmes. Despite the relatively small subsidy from METI (handled through NEF), this subsidy is very often the seed for additional local Government support, which would otherwise probably not be given.

The new Renewable Portfolio Standard (RPS) was drafted by METI and passed by the Diet in spring 2002. The bill obliges power retailers, from FY 2003 on, to sell certain amounts of renewable energies. The legislation is aimed at tripling the FY 1999 ratio of new energy in the total power supply to 3.2% in FY 2010 (currently: 0.2% is RE excluding hydro and geothermal; target here 1%) as part of Japan's efforts to attain the greenhouse gas reduction target under the Kyoto protocol. The bill requires each power retailer to set an annual sales target for six types of renewable energies: sunlight, wind, terrestrial heat, water and “sources other than oil that the government specifies”, which may include biomass and waste. METI will set the aggregate targets (with special treatment of PV) for the use of the different new energies in the coming eight years, and this will serve as the basis of the annual target calculations by each energy retailer. Each retailer will be required to report to the Ministry its specific targets for the coming year and results from the preceding year. The companies could achieve their targets either by generation of new energy with own facilities, buying electricity from authorised new energy generators or buying surplus from other retailers. The exchange of surplus will be handled by certificates issued by METI. These certificates will be valid for two years and issued for every 1000 kWh of renewable energies generated. A company which fails to meet its target in the initial year will be allowed to pay METI in the following year an amount of certificates equivalent to its annual target, plus the first year shortage. RPS will replace the pay-back system, but METI will set frame conditions to ensure future growth of PV installations.

3.3 NEDO PV Programme

The current programme is called “Projects for New Energies”. Compared to the last phase of the New Sunshine Project there are now fewer companies involved. The reason for this development is on the one hand a concentration amongst the Japanese PV producers and on

³ Used exchange rate: 1€ = 117¥

the other hand, a temporary suspension of companies from the programme, which have been accused of misconduct in the past.

Due to the administrative reform of the Japanese governmental structure, NEDO has now a new structure (independent governmental entity) and a new role in the execution of the photovoltaic programme. The New Sunshine Project Headquarters was abandoned at the end of FY 2000. Taking effect in FY 2001, NEDO replaced the New Sunshine Project by a programme named “Advanced PV Generation” (APVG). As result of the New Sunshine Project (NSP or NSS) evaluation, several important priorities were selected.

- Technology Development for Future Mass Deployment
- Advanced Manufacturing Technology
- Advanced Solar Cell technology
- Innovative PV Technology

One of the dominant priorities, besides the future increase in PV production, is obviously the cost reduction of solar cells and PV systems. The two main funding tools for R&D issues are:

First:

Seed identification with respect to production technologies, industrialisation and commercialisation. These measures receive funding up to 50% by NEDO with matching funds by the participating companies.

Second:

APVG, this is a 100% NEDO sponsored R&D activity carried out by selected research institutions and companies. **This activity includes the 100% NEDO sponsoring of pilot plant developments for new PV technologies (an action which is completely missing in Europe!).**

In addition to these activities, there are programmes on future technologies (in and outside NEDO) where participation is for Japanese institutes or companies on invitation only. For the participation of non Japanese partners there are “future development projects” and the NEDO Joint Research Programme, mainly dealing with non applied research topics.

Feedstock problem: METI supported a programme concerning the melt purification process of metallurgical silicon. According to the information given, Kawasaki Steel will start solar-grade manufacturing with approximately 500 to 1000 t/year in FY 2002. In addition there will be a one-year project for FY 2002 to investigate the possibilities to start solar grade silicon production with a simplified Siemens process. However, NEDO has made a survey amongst the Japanese manufacturers, which do not see the problem critical until 2004/5. In addition it is believed that industry itself will take responsibility for this problem if the current growth rates continue.

Mass Deployment of PV: A focus of this activity is the system development. NIAIST (former ETL; now an independent governmental entity) is responsible for this. The following topics are dealt with:

- Performance of systems
- Recycling issues (**very important**)
- Electromagnetic compatibility (EMC) - focused on central inverters
- only little activity on AC modules

Under the current NEDO PV programme, only seven PV companies were awarded research contracts. The following price targets are calculated for a 100 MWp/year production.

(1) Development of advanced solar cell modules

a-Si/ μ -Si: Kaneka and Mitsubishi Heavy Industries:
target for 2005: $\eta = 12\%$ for a 3600 cm^2 prototype module; 100 ¥/Wp

CIS: Showa Shell Sekiyuki (glass substrate) and Matsushita Electric (roll to roll):
target for 2005: $\eta = 13\%$ for a 3600 cm^2 prototype module; 100 ¥/Wp

Super high-efficiency compound solar cells:

- **Concentrator:** Sharp (cell), Daido Steel (module; concentrator) and Daido Metal (system; tracking); Sharp took over the equipment and results from Japan Energy, no longer continuing PV research. Current standing: Inp/GaAs 3-junction stacking with 32% without concentration. Planned is a 500C module.
target for 2005: $\eta = 40\%$ prototype module; 100 ¥/Wp
- **High efficiency multi-crystalline Si (cast Si) solar cells:** Kawasaki Steel, Sumitomo Metal, Sharp
target for 2003: $\eta = 20\%$ for a $15 \times 15 \text{ cm}^2$ cell; 147 ¥/Wp

CdTe: stopped

(2) Development of Evaluation, Recycling and other Infrastructure technologies

- **Evaluation techniques of solar cells and modules:** AIST⁴, JET⁵
- **Evaluation techniques for PV systems:** AIST, JET
- **Development of recycling techniques:** Sharp, Showa Shell, Asahi Glass, AIST, PVTEC
- **Research on EMC in PV systems:** JET

(3) Development of innovative, next-generation PV systems

- **CuInS₂ thin film solar cell by electroplating:** Shinko Electric

⁴ National Institute of Advanced Industrial Science and Technologies (former ETL)

⁵ Japan Electrical Safety & Environment Technology Laboratories

- **Nano-structure Si thin film solar cell:** AIST, Kyushu University, Toppan Printing, Stanley, Nippon Sheet Glass
- **SiGe-based solar cell:** Tohoku University
- **Solid state dye-sensitised cell:** University of Tokyo, RITE, TIT
- **Low cost manufacturing technique by CAT-CVD:** JAIST, Osaka University, Gifu University
- **β -FeSi₂ solar cell:** System Engineers, AIST
- **Ultra-efficient confinement:** Asahi Glass
- **Silicon ball solar cell:** Clean Venture 21 (Hamakawa, Wada, Matsushita Electric)
- **Low cost and high efficiency dye sensitised cell:** AIST, Sumitomo Osaka Cement, Furukaw Machinery, Hayashibara Biochemical Lab, Sharp

3.4 Japanese Market Situation and Roadmap

The Japanese photovoltaic production has rapidly increased following the development of roof-type technologies and the introduction of the subsidy system “Programme for the Development of Infrastructure for the Introduction of Residential PV Systems” in 1997. Despite the current recession, the sales of PV systems has increased steadily even when the growth rates were somewhat lower than anticipated in 2001. The assurance that the subsidy system for residential PV systems would be in place at least from 1997 to 2002, has encouraged housing manufacturers to promote the integration of PV systems in new houses. In the meantime, PV systems are an additional added value for existing or new houses as an increasing number of Japanese consumers are considering their lower environmental impact by using a PV system more important than the higher price.

After 30 years of PV development under the different NEDO programmes, there are at present only 5 to 6 Japanese PV manufacturing companies on the market. In addition there are a few module manufacturers as well as inverter and glass producers. Currently approx. 50% of the world-wide PV manufacturing capacity (200 MW) is in Japan, but in order to reach the target for PV installations set for 2010 at 4.8 GWp, the increase of the production capacity has to be further accelerated. A special constellation of the Japanese PV industry is the fact that a few large companies bundle the whole or at least large portions of the PV value chain inside their own company, i.e. the solar cell, BOS components and sometimes even the installation and maintenance of the PV systems are offered from the same company. This development is fostered by the special situation of the Japanese construction market. The average lifetime of a residential home is about 25 years and corresponds well with the lifetime of solar modules. A lot of houses are either prefabricated or the construction companies use standardised building

components, which is favourable of the integration of solar modules. This advantage was recognised by the solar cell manufacturers and they have either bought housing or construction companies, or concluded strategic alliances with such companies. In 2001 approx. 45% of the solar cells sold world-wide were produced in Japan (176 MW). The current expansion of production capacities in Japan makes it likely that this market share will even rise in the future.

For a housing company in Japan the promotion of PV can be successful due to the following reasons: The availability of PV modules is secured by the fact that the world's largest PV manufacturers are located in Japan. Due to the limitation of available space and the high land prices in Japan, the rooftop or building integration is the most economical solution. The grown environmental awareness of the Japanese customer led to the concept of the Life Cycle Cost (LCC) for the total building. This LCC includes the CO₂ emission of the house from building, operation and maintenance until the demolition and recycling. Smart concepts for building materials, implementation of building isolation and integration of PV lead to better LCCs, compared with conventional houses. This fact is a strong selling argument for housing companies towards environmental concerned customers.

In addition, the integration of the PV system at an early stage in the planning of prefabricated and mass manufactured houses offers the chance for a significant price reduction of the PV systems compared to individually built houses or add-on PV systems. For example, to offer stainless steel roofs and aluminium shadings, the advantage of low maintenance costs while being able to be used as PV substrates at the same time. This combination of functions add to the cost reduction for the PV system. In addition an average 3,4 kWp system leads to a saving in energy costs of approx. 80.000¥ (3250 kWh). This leads, together with the subsidy of 340.000¥ (2002) for the investment costs, to an approximate monetary pay-back time of 14 to 15 years. With a lifetime expectation of the PV system of 20 to 25 years, this is an additional incentive for the customers. The pre-installation and mass fabrication of the unit homes, enable the manufacturer to limit the actual installation work of the PV system on the building site to the optimisation of the PV power performance and therefore, lead to considerable savings for the installation. In order to attract a large variety of customers housing companies offer a large variety of PV systems with different sizes and technologies. The choice of technology, depends on the customers' option for system size and design.

The shrinking markets for classical heavy machinery equipment on the one hand and the dynamic growing PV market as well as the promising outlook for future growth have drawn the attention of manufacturers like Mitsubishi Heavy Industries, Ltd. to invest in solar cell production technology. New Energies and PV were identified as a high potential new market by the "PM Advisory Committee of Competitiveness". PV manufacturing is now rated by the Japanese Industry as a "key industry" which should not be shifted to China or other Asian

countries, but done in Japan. These comments and findings reflect the emotional change in Japanese Industry and Politics towards PV since 1997.

In the framework of the last evaluation of the “New Sunshine Project” NEDO, METI, PVTEC⁶ and JPEA⁷ drafted a roadmap for PV research and development as well market implementation activities for the next 30 years. This roadmap reflects the research activities described in the previous chapter and their impact on the industrial progress (Fig. 5).

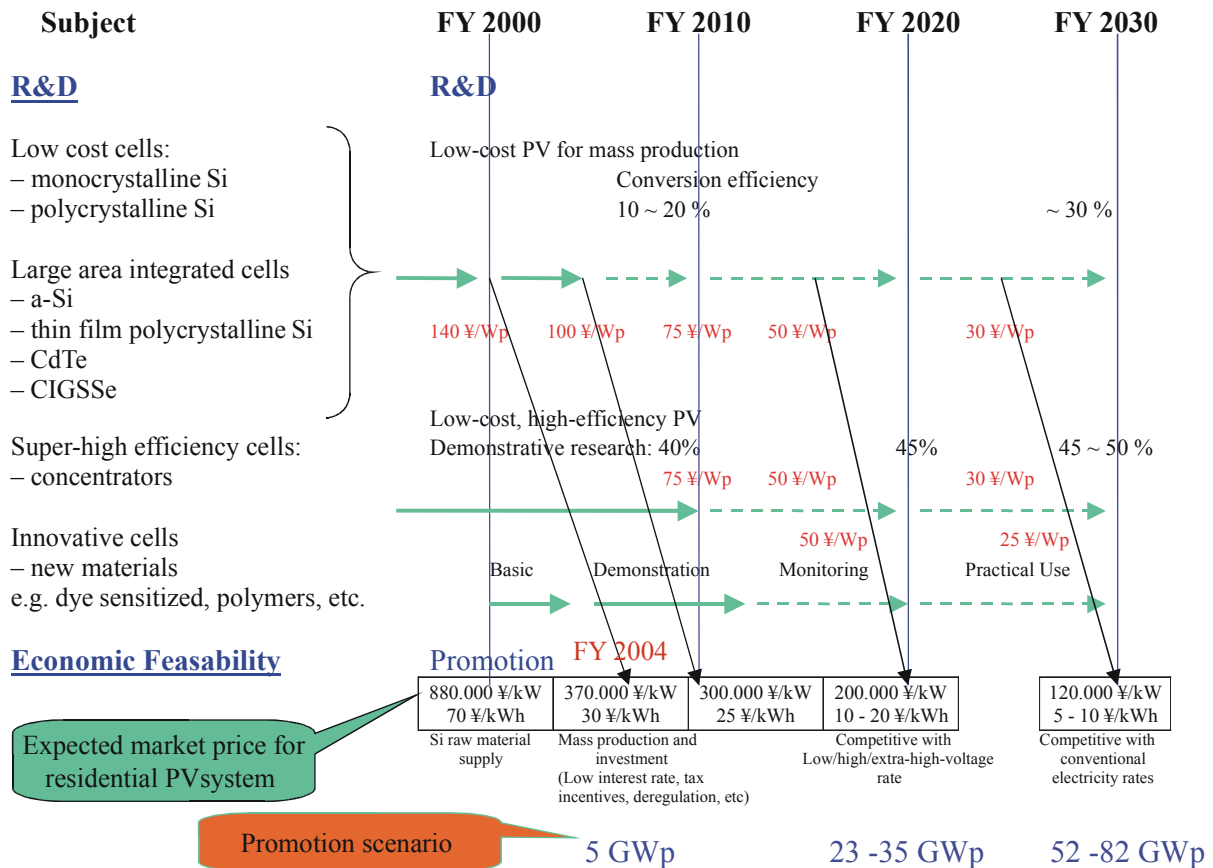


Fig. 5: Japanese roadmap for PV R&D and market implementation

During this evaluation, the following connections were identified between research and development on the one side and market implementation of photovoltaics on the other side, which are of strategic importance for the shaping of future R&D programmes[11].

- To realise the scenario of mass production of solar cells and low costs for PV systems it is indispensable to stimulate technical R&D, as well as market implementation at the same time.

⁶ Photovoltaic Power Generation Technology Research Association

⁷ Japan Photovoltaic Energy Association

- It is essential to define price/cost targets for R&D processes. Such targets are always the best motivation for private companies to undertake own R&D endeavours, as soon as markets emerge.
- Roof integrated PV systems have developed in Japan into a promising market and ensure penetration in large numbers. This behaviour might also be explained by the quite high electricity price in Japan of approx. 25 ¥/kWh for private customers.
- Despite the rapid advances of PV technology in industry, it is indispensable to promote R&D projects dealing with new types of solar cells aimed at realising PV systems for lower costs. In parallel it is important to use the current PV technology to be put into practical operation and generate a PV market. To realise this goal, it is necessary to get PV systems recognised by the market players and to meet the customer demand for price, design and quality. To do so, leading companies are required to make great efforts as pioneers and create a market.
- Education and training for architects, designers and installers of PV systems are essential to establish and maintain a market and its infrastructure. It is important to understand that a market is never created just because a new technology has been developed.
- Deregulation for PV system business, safety and environmental requirements can eventually promote the penetration of PV systems to the same extent or even more than promotion measures may do.
- To realise the scenario of mass production and low costs for PV systems, it is further important that big companies or consortia, which have the ability to place and receive large orders for PV systems in bulk with good sales logistics, e.g. trading companies, appear on the stage. In Japan, housing companies have played a significant role to increase orders for PV systems. Approximately 500 000 new houses are built in Japan every year and the activities of the housing companies in marketing PV systems have led to a significant increase of orders for the PV manufacturers. Normally 50% of the PV systems sold in Japan each year are sold with a new house. The advantage for the customer is the lower price of the system, completely integrated into the new house and the low financing costs, as the additional costs are included in the house loan.

3.5 Major market players

In the following, most of the major market players in Japan are described briefly. This listing does not claim to be complete, especially due to the fact that the availability of information or data for some companies were only very fragmentary.

3.5.1 Sharp Corporation

Sharp started to develop solar cells in 1959 and succeeded in mass-producing them in 1963. Since its products were mounted on "Ume", Japan's first commercial-use artificial satellite, in 1974, Sharp has been the only Japanese maker to produce silicon solar cells for use in space. Another milestone was in 1980, with the releases of electronic calculators

equipped with single-crystal solar cells. In addition, Sharp has been successfully installing solar modules up to 1,223 locations of lighthouses in Japan.

Sharp is currently the world largest PV cell and module manufacturer with a production capacity of 148 MWp/year (July 2002). In 2001, 75 MWp were shipped. According to the business plan for 2002, Sharp is currently under way to increase the production capacity to 200 MWp/year and is planning to reach this by the end of FY 2002. Due to this development and to promote further business expansion, Sharp's Photovoltaics Department was upgraded to become the Solar Systems Group in January 2002.

Within the last 5 years Sharp has sold more than 56,000 PV systems for residential use. Sharp has a close collaboration with Japanese major housing companies. Sharp offers complete PV systems with all components made within the company (Fig. 7). At the moment the residential PV market is the driving force for the capacity expansion, but Sharp considers future growth in the industrial sector as well. Therefore, Sharp plans to offer the installation and service of large PV systems (in the range of a few hundred kWp) for industrial clients.

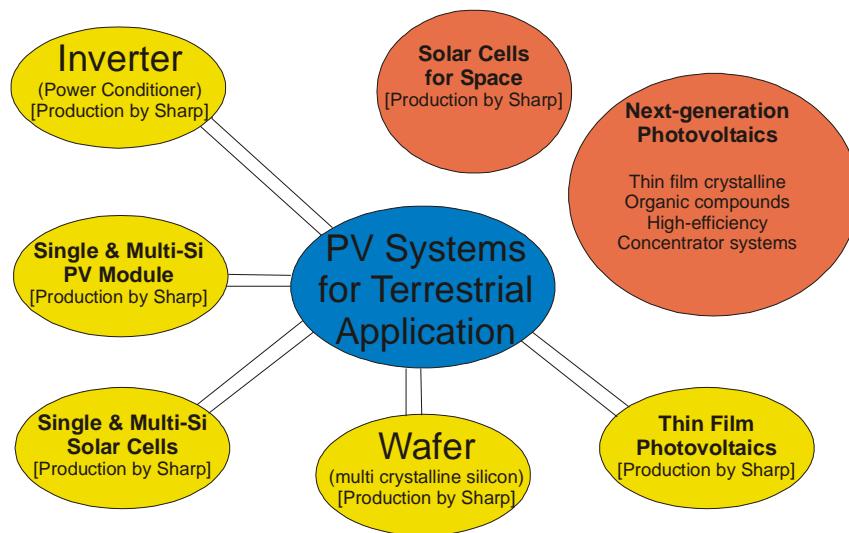


Fig. 6 Development concept of Sharp

Concentrator Systems: Sharp is involved in developing super high-efficiency Compound Solar Cells and low cost solar concentrator modules and systems, together with Daido Steel and Daido Metal within a NEDO research project. At the moment Sharp is not in a position to prospect its production yet.

3.5.2 Kyocera Corporation

In 2001, Kyocera Corp. had sales of 54 MWp and is marketing systems that both generate electricity through solar cells and exploit heat from the sun for other purposes, such as heating water. The new products will take advantage of a new government subsidy made available in April 2001 for systems using solar heat. The Sakura Factory in Chiba prefecture is involved in

everything from R&D and system planning to construction and servicing and the Shiga factory, in Shiga prefecture, is active in R&D, as well as the manufacturing of solar cells, modules, equipment parts, and devices, which exploit heat. Like the other Japanese manufacturers, Kyocera is planning to increase its capacity. According to Keizai Shinbun (September 2002) the Shiga factory has a current capacity of slightly more than 60 MW. The planned capacity will be increased by 20% by the end of FY2002 and to 100 MW by the end of FY2003.

Kyocera is primarily active in R&D and the production of solar cells used to generate electric power. Kyocera is working to create more efficient, lower-priced solar cells with a larger surface area and reduced thickness by developing further the multicrystalline silicon solar cell technology.

In 1975 Kyocera began with research on solar cells. The Shiga Yohkaichi Factory was established in 1980 and R&D and manufacturing of solar cells and products started with mass production of multicrystalline silicon solar cells in 1982. In 1993 Kyocera achieved a 19.5 % world record efficiency with single-crystal silicon solar cells (10 cm²). In the same year Kyocera started as the first Japanese company to sell home PV generation systems. Today they are the second largest PV manufacturer in the world.

3.5.3 SANYO Electric Company

Sanyo started R&D for a-Si solar cells in 1975. 1980 marked the beginning of Sanyo's a-Si solar cell mass productions for consumer applications. Ten years later in 1990 research on the HIT (Heterojunction with Intrinsic Thin Layer) structure was started. In 1992 Dr. Kuwano (now the president of SANYO) installed the first residential PV system at his private home. Amorphous Silicon modules for power use became available by SANYO in 1993 and in 1997 the mass production of HIT solar cells started. Current production capacities are 30 MWp HIT and 5 MWp a-Si. According to the Nihon Keizai Shinbun (August 2002) Sanyo plans to increase its production capacity by 40% by the end of FY2002 and up to 120 MW by 2005 [12].

Sanyo has set a new world record for the efficiency of the HIT solar cell with 21%. This technology offers Sanyo the possibility to produce PV systems, which need less space per kWp. This is a sales argument especially for small area installations on small Japanese houses. In addition, the HIT technology has a lower thermal budget for producing the cell and the wafer can be thinner than with conventional cells. This leads to savings in the material used as well as production energy. The HIT structure offers the possibility to produce double-sided solar cells, which offer the advantage to collect scattered light on the rear side of the solar cell and can therefore increase the performance by up to 30% compared to one-sided HIT modules in the case of vertical installation. This application is interesting for sound barriers, rooftop fences or horizontal installation as carports, etc. For October 2002 Sanyo announced the

release of their latest version of the HIT module with 18.5 % cell efficiency and 16.1 % module efficiency.

Sanyo is working together with Daiwa House to promote the HIT power roofing tile. The advantages are a lower weight (50%) compared to a conventional roof tile. Like other big Japanese solar companies Sanyo offers the complete PV systems manufactured by its own factories. As part of its solar product strategy, Sanyo Electric acquired home builder Kubota House Co. (since renamed Sanyo Homes Corp.) in 2001 to market houses with roofs incorporating solar cells, according to Shigeru Nomoto, general manager of Sanyo's Clean Energy Division [12].

Solar Ark Project: The "Solar Ark", a large scale Solar power generation system (630 kWp) at SANYO's Gifu facility was completed in December 2001. The Solar Ark was built in the image of an Ark embarking into the 21st century powered by solar energy. The Ark's total length measures 315 meters, its highest point measuring 37.1 meters (31.6 meters at its centre point) making it the largest single structure solar installation in the world. Power generation began in April 2002. Placed underneath the Arch is the "Solar Lab", a Solar Energy Museum opened on 3 April 2002. The main activities are:

- Cultivate Children's awareness in Science and Ecology.
- Release of information from the standpoint of benefiting mankind and the environment.
- Regional contribution such as support for the development of Eco-Town.
- Creation of new ideas through various activities.

3.5.4 Kaneka Solartech

Kaneka has been involved in the development of amorphous solar cells for 23 years. At the beginning this was aimed at the consumer electronics market, but the overall R&D as well as business strategy was changed in 1993. At this time Kaneka decided to move into the power module market for residential and industrial applications. The goal set was to mass-produce a-Si Modules for rooftop applications by 1999. Besides economical consideration, one of the main reasons for this decision was the fact that Dr. Kenji Yamamoto found a possibility to deposit microcrystalline silicon at a low enough temperature (200°C) to combine it with an a-Si solar cell and was able to patent this method. The patents on the previous important findings (Hydrogenated a-Si solar cell, Carlson, RCA 1976; pin a-Si solar cell, Hamakawa, Osaka Univ. 1978; integrated a-Si solar cell, Kuwano, Sanyo 1979 and a-SiC/a-Si heterojunction solar cell, Tawada, Kaneka 1981) will expire until 2002, so that this decision looked fairly economically backed. The planned cost target was to reach half of the c-Si with an annual capacity of 40 MWp.

Currently Kaneka produces a-Si modules for rooftop application and built in roofing types for the Japanese, as well as export markets. The built in roofing types were developed for the

Japanese housing market in co-operation with Quarter-House and Kubota and are either shingle type modules or larger roofing elements. The total production capacity is currently 25 MWp/year with an estimated output for FY 2002 of 15 MWp. The locations are Shiga (5 MWp) and Toyooka (20 MWp). It is planned to increase the production capacity of the Toyooka plant to 40 MWp in the near future (probable start of operation FY 2003). An important market with future potential is at present Germany with 2 MWp a-Si modules in 2001 (due to the high demand following the introduction of the feed-in tariff) and in the future Europe.

The a-Si modules are rated with 8% stabilised efficiency and Kaneka guarantees that the power output will not drop below 80% of the nominal value for 20 years. In FY 2001 they now started to produce the “10% hybrid module” with an average stable efficiency of 10.5% for which they guarantee at least 9.8% with the 10% deviation over 10 years.

Kaneka’s Plans for the thin film PV business can be summarised as follows:

- The system price with 7.5% a-Si modules and 10% hybrid modules in 2002 is 1.5 million ¥ for 3 kWp.
- In 2005, 12% hybrid modules are planned with a system price of 1.2 million ¥ for 3 kWp.
- In 2006, increase to 13% hybrid modules with a system price of 1.0 million ¥ for 3 kWp.
- In 2010, 16% hybrid modules should be realised with a system price of 0.6 million ¥ for 3 kWp.

This technological development depends on the realisation of an increase in the deposition rate for the polycrystalline silicon, due to the necessary larger thickness of this layer. The production yield of 97.1% already reached is remarkable. The main losses are “Low Performance” (1.4%), these are modules which deviate more than 10% from the set target of 10.5% and “Cosmetic Defects” (1.1%).

So far the “Hybrid PV Modules” (a-Si/polycrystalline silicon thin film) are only sold to Japanese customers, as the certification for Europe is still missing. Therefore, Kaneka Solartech is very much interested in field-testing their hybrid modules in order to learn about the outdoor performance at different locations world-wide. Another urgent issue is the development of testing standards for the hybrid multi-junction cells and modules, as the performance differs very much according to the solar spectrum, air mass and relation of direct/diffuse solar radiation. Under the standard test conditions using a solar simulator the standard hybrid module (3738 cm²) shows an efficiency of 11.57% with a power output of 43.24 W, whereas the outdoor measurement in Otsu, Shiga, (T = 31.8°) led to an initial efficiency of 12.3% and a power output of 46.0 W.

3.5.5 Mitsubishi Heavy Industries

Mitsubishi Heavy Industries (MHI) is a new player in the PV manufacturing business. Solar energy has attracted increasing attention as an environment-friendly form of energy. According to MHI's business plan 2002 [13], a facility for the mass production of solar cells was completed on the grounds of the Isahaya plant of its Nagasaki shipbuilding facility in February 2001. The mechanical construction of the production line was finished in December 2001. The new plant has high-speed production equipment and is scheduled to begin producing solar cells with an annual production capacity of 10MW from autumn 2002.

Compared with crystalline solar cells, MHI's amorphous solar cells can supply energy more inexpensively and are therefore expected to make a considerable contribution to environmental protection. The used plasma CVD deposition allows rapid deposition on large size glass and flexible substrates (roll to roll). MHI has stabilised the a-Si single-junction efficiency at 8%, starting with 10% initial efficiency. The degradation process lasts for approximately 3 to 4 months before the stabilised efficiency is reached. Long-time outdoor exposure tests performed at JQA showed that the stabilised efficiency does not change and that the lifetime expectancy can be rated at 20 to 25 years. Mitsubishi is currently working on improving the efficiency to 12% by using a microcrystalline/a-Si structure in the future. Another feature of the Mitsubishi modules is their high voltage. The modules are produced with either 50V or 100V and power ratings between 24 and 100Wp.

One of the main reasons given for the solar cell activities at Mitsubishi Heavy is the increasing market for photovoltaic systems, as well as the promising outlook of the future growth of this field. Why did Mitsubishi Heavy invest in the amorphous silicon technology? The answer to this question lies in the portfolio of the company. The core technologies for the a-Si manufacturing, were already well established business sectors: deposition technologies for large scale thin film deposition and the manufacturing of the respective machinery. Especially the fact that Mitsubishi has the equipment development in-house enables a fast feedback and improvement of the production technology.

The marketing strategy of Mitsubishi Heavy Industries aims to build on a commodity image. Together with a large Japanese housing company they developed specially designed roofing tiles for the Japanese market. According to the company, these roofing tiles could easily be adapted to other markets if necessary. The design of these tiles was made together with the housing company as well as architects, in order to ensure a wide acceptance of the product. Other module types are being developed for industrial buildings and industrial clients (large-scale application). The same approach is taken for the development of facade modules.

4. PV IN THE UNITED STATES

In special market segments and local markets PV is becoming more and more competitive. Within the last decades, the US spent approximately 1.7 bill. \$ of public funds for the development of photovoltaic technologies. Despite the fact that the envisaged price reductions have not been reached yet these investments have already paid off. The continuous improvement of the technologies and the development of markets indicate the potential of a higher return on investment.

The Solar Electricity Power Association (SEPA) has made a study about the current status of PV in the US with the title “The Solar Power Solution”, which was presented in April 2002 [14]. This study concentrates on the factors critical to the success of a constructive and focused path forward for PV in the years ahead. The support for renewable energies from US states and local initiatives (utilities, municipalities, etc.) have surpassed federal support (2001: 66 mill. \$ federal funds out of 470 mill. \$ total). The opinion of SEPA is that federal funding and policies should be better leveraged to support and link together the manifold state and local activities. In November 2001, 33 US states already had measures for net-metering electricity produced by PV. However, one of the main problems of PV is the lack of infrastructure in the areas of sales, marketing, as well as installation and maintenance of PV systems. In addition, a standardisation of PV systems according to IEEE standards is missing. This is not only a technical problem, but prevents further cost reduction by the use of cheap standard installation components. According to SEPA there is an urgent need for more highly visible demonstration and education projects to show the public the advantages and possibilities of PV systems. In general the federal government should make more information available to the public.

There is no single market for PV in the US but a conglomeration of regional markets and special applications for which PV offers the most cost-effective solution. Until recently the PV market has been dominated by off-grid applications, such as remote residential power, industrial applications, telecommunications and infrastructure, such as highway and pipelines lighting or buoys. For these applications PV is not only cost effective but the market shows a continuing growth potential.

According to the SEPA study, the markets for grid-connected PV are less mature but due to market implementation programmes have increased tremendously in recent years and provide the largest potential for growth. These applications include PV for residential and commercial buildings as well as government facilities. To develop and expand these markets targeted approaches are required.

Currently the US market can be classified in four categories, where according to the local electricity costs, net-metering and market incentives the listed turn key price for a PV system allows competitive PV electricity production.

<p>Best markets: (red) above 7 \$/Wp; 5 states: California, Hawaii, Illinois, New York, North Carolina</p>	<p>Emerging markets: (green) between 3 \$/Wp and 4,5 \$/Wp; 6 states Nevada, New Mexico, North Dakota, Delaware, Connecticut, Maine</p>
<p>Cost effective markets: (yellow) between 4,5 \$/Wp and 7 \$/Wp; 10 states + DC Arizona, Utah, Colorado, Massachusetts, Rhode Island, Pennsylvania, New Jersey, Maryland, Virginia, Florida, Washington DC,</p>	<p>Significant incentives needed: (blue) below 3 \$/Wp; 29 states</p>

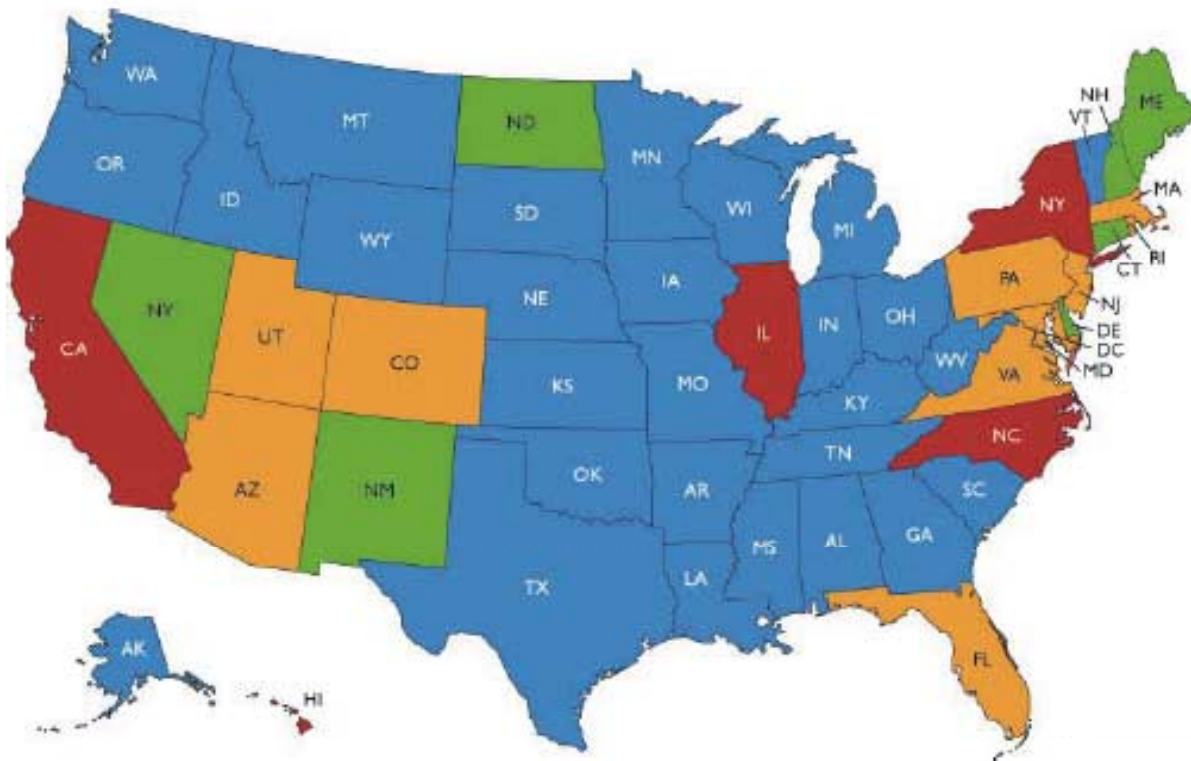


Fig. 7: US-PV-markets [Figure: SEPA]

Although the majority of US states are in the category where significant incentives are needed, one has to note that a quarter of the U.S. population lives in the top five states for PV. In those states, PV is cost-effective at an installed cost of \$7/W (assuming long-term financing as in a mortgage). These five states belong also to those states with the highest economic

potentials. In addition it has to be noted that half of the population lives in states in the top two tiers, where PV is cost-effective at a cost of \$4.50/W⁸.

One of the most promising programmes for the promotion of photovoltaics, which is under discussion, is to use renewable energies and especially PV for electricity generations on Federal Land and in National Parks. The Ministry of the Interior is in charge of implementing this programme, as they are responsible for these lands. PV systems would have a double advantage. First, PV systems are the most reliable and cost effective solution for electricity generation in remote and environmentally sensitive areas. Second, due to the fact that a lot of people are visiting these Parks, they could serve as demonstration systems, which provide first hand information about the benefits and prospects of PV systems. A similar programme, albeit for different reasons, is being discussed at the Ministry of Defence. However, SEPA could not give any information about details or the the status of the discussion.

The new National Energy Plan scheduled to come into effect in 2003 includes, similar to Japan, the introduction of a „Renewable Portfolio Standard“ to promote the use of renewable energies and photovoltaics. It is still not decided how the RPS should be shaped and whether or not penalties for companies, which do not fulfil their targets should be included. At present, the arbitration panel of the US Senate and the House of Representatives, is dealing with the RPS. The reason is that the endeavours of Jeff Bingaman, chairman of the US Senate energy committee, made the RPS a central issue in the Senate legislature and is in contradiction to the bill drafted by the House of Representatives. There are hopes, that during the autumn of 2002 the final bill will be passed and that the RPS will promote in a lasting way the implementation of renewable energies in the US.

4.1 Incentives supporting PV

Due to the political situation in the US, there are besides the RPS and some federal tax breaks, no uniform incentives for market implementation of photovoltaics. The 1 000 000 solar roof initiative signed by President Clinton in 1997 lacks a dedicated budget and the Department of Energy (DoE) can only support measures for the removal of market barriers or the development of local promotion programmes. In the framework of state and local initiatives and partnerships, approximately 150 000 systems have been installed since 1997.

Many state and Federal policies and programmes have been adopted to encourage the development of markets for PV and other renewable technologies. These consist of direct

⁸ Based on data from US Census 2000

legislative mandates (such as renewable content requirements) and financial incentives⁹ (such as tax credits). Financial incentives typically involve appropriations or other public funding, whereas direct mandates typically do not. In both cases, these programmes provide important market development support for PV. The types of incentives are described below. Amongst them, investment rebates are the most commonly used – at least 37 states, in all regions of the country, have such programmes in place. The most common mechanisms are:

- personal tax exemptions (15 states)
- corporate tax exemptions (17 states)
- sales tax exemptions for renewable investments (14 states)
- property tax exemptions (23 states)
- buy down programmes (10 states; 23 utilities)
- loan programmes and grants (24 states; 7 utilities)
- industrial recruitment incentives (9 states)

4.1.1 Federal Incentives

Production Tax Credit: The Energy Policy Act of 1992 (EPAct) provides an incentive of 1.5 cents/kWh (1993\$) for generation from solar and other renewable sources during their first 10 years of operation. The incentive – Renewable Energy Productive Incentive (REPI) – is only available to tax-exempt publicly owned utilities, local and county governments and rural cooperatives¹⁰.

Qualifying facilities must use solar, wind, geothermal (with certain restrictions as contained in the rule making), or biomass (except for municipal solid waste combustion) generation technologies.

Taking into account inflation, the current incentive is equivalent to 1.7 cents/kWh. This is not a very significant incentive given the current cost of PV electricity, but it might be as high as 10% of the system cost in some cases. SMUD, among others, has benefited from this.

There are two tiers or technology classifications in REPI: Tier 1 is solar, wind, geothermal, and closed-loop biomass. Tier 2 includes open-loop biomass technologies, such as landfill methane gas, biomass digester gas, and plant waste material that is co-fired in a generation facility to generate electricity. REPI funds are first distributed to qualifying Tier 1 facilities; then, remaining funds are allocated to Tier 2 facilities. Historically, Tier 2 facilities have been

⁹ DOE has defined a financial incentive as one that: (1) transfers economic resources by the Government to the buyer or seller of a good or service that has the effect of reducing the price paid or increasing the price received; (2) reduces the cost of producing the good or service; and/or (3) creates or expands a market for producers. EIA, “Renewable Energy 2000: Issues and Trends,” section on “Incentives, Mandates, and Government Programs for Promoting Renewable Energy,” Mark Gielecki, Fred Mayes, and Lawrence Prete.

¹⁰ For FY 02, the House Energy and Water Appropriation Committee recommended \$4M for REPI.

the major recipient of the funds, but this is changing as wind installations increase. Table 2 shows REPI payments to PV systems.

Federal Business Investment Tax Credit for Qualifying Energy Property: EPAAct also provides a tax credit for business investment in solar and geothermal generating equipment. Up to 10% of the investment or purchase and installation amount of qualifying energy property can be claimed by a business when filing annual tax returns. Qualifying energy property includes equipment that:

- Uses solar energy to generate electricity, to heat or cool (or provide hot water for use in) a structure, or to provide process heat; or
- Produces, distributes, or uses energy derived from a geothermal deposit.

Table 2: REPI Payments for PV Systems

Year of production	Year of payment	PV Facilities	PV Payments (thousand \$)	Tier 1 Payments (thousand \$)	Total REPI
1994	1995	2	8	101	693
1995	1996	4	15	219	2397
1996	1997	9	28	196	2490
1997	1998	2	31	155	2854
1998	1999	3	91	122	4000
1999	2000	5	46	603	1500
2000	2001	6	53	1339	3991

Source: Office of Power Technologies, <http://www.eren.doe.gov/power/repi.html>

For electricity produced from geothermal power, equipment qualifies only up to, but not including the electrical transmission stage. There are exclusions for public utility property and reductions on the amount of credit claimed if the qualifying property is/was financed by subsidised energy financing or by tax-exempt private activity bonds.

Federal Modified Accelerated Cost Recovery System: Section 168 of the Internal Revenue Code contains a Modified Accelerated Cost Recovery System (MACRS) by which businesses can recover investments in solar, wind, and geothermal property through depreciation deductions. The MACRS establishes a set of class lives for various types of property, ranging from three to 50 years, over which the property may be depreciated. For solar, wind, and geothermal property placed in service after 1986, the current MACRS property class is five years. The property (equipment) allowable by MACRS must meet the same standards for

eligibility required by the Federal Investment Credit (see above), with the inclusion of wind energy systems¹¹.

Federal Tax Exemption for Nontaxable Energy Grants or Subsidised Energy Financing: Energy grants and subsidised energy financing received by a business from Federal, state, or local government entities may be exempt from Federal taxation. Such grants and financing must be for the principal purpose of conserving or producing energy. The administrator of the grant or financing must report disbursements of such funds to individual businesses using IRS Form 6497. The business/recipient of the grant or financing should ensure that the administrator of the grant or financing files Form 6497 with the IRS. It is the administrator's responsibility to notify the recipient of the grant or financing that the grant or financing is nontaxable¹².

Federal Support for Renewable Energy Project Development: The Federal government has various programmes and mechanisms that may provide funds or financing to support renewable energy projects. In general, these funds are available under specific programmes of specific agencies and are dependent on annual appropriations from the U.S. Congress. The U.S. Department of Energy (DOE) has funding programmes focused on developing new technologies, and from time-to-time may have funds available for project feasibility studies and even technology demonstrations. Most focus on specific technologies or applications, and are often cost-shared.

4.1.2 State Incentives

Many state and local governments offer one or more of a broad range of financial incentives for investment in PV and other renewable energy technologies. These incentives include:

- ***Income Tax Credits***, which allow personal income tax deductions for PV and other renewable investments. Hawaii, for example, allows individuals to deduct 35% of the cost of equipment and installation of residential PV and solar heating systems, up to a maximum deduction of \$1,750 for houses and \$350/unit in multi-unit complexes.
- ***Property Tax Exemptions***, which exempt the value of PV and other renewable systems from the property values on which taxes are assessed. For example, Texas exempts taxpayers from any value added by a qualified solar and wind energy equipment for property tax purposes.

¹¹ For more information on and to claim MARCS see IRS Form 4562: Depreciation and amortisation and Instructions for Form 4562, and Internal Revenue Code Sec. 168 (e)(3)(B)(vi).

¹² Generally, reporting on Form 6497 is required only for nontaxable energy grants and subsidised energy financing made for Section 38 property, as defined in Section 48 and the regulations under Section 48, of the Internal Revenue Code.

- **State Sales Tax Exemptions**, which exempts sales of qualifying renewable energy generating or heating equipment from state retail taxes. Arizona, for example, exempts PV and solar heating equipment from state retail taxes, up to equipment values of \$5,000.
- **Loan Programmes**, which provide low-interest loans to residential and commercial investments in PV and other renewable equipment. Whatcom County, Washington, for example, offers a revolving loan fund for low-interest loans for grid-tied PV and solar thermal systems in residential and commercial applications. Loans are available for up to \$5,000 with up to 25 years for repayment.
- **Investment Rebates**, in which a portion of the cost of solar projects is rebated by the government. Delaware, for example, rebates 35% of the cost of qualified PV and solar hot water systems to residential and commercial investors. It provided a \$1 million budget for the rebate programme in 2000.
- **Industry Recruitment Incentives**, which essentially exempt qualifying renewable-industry businesses from corporate and/or other taxes. Texas, for example, exempts solar equipment manufacturers, sellers or installers from its franchise tax (essentially equivalent to a corporate tax). There is limit to the value of this exemption in Texas.
- **Project Development Grants**, which provide funding for a portion of the cost of new qualifying PV and other renewable projects. These grants are typically funded by “public benefit funds” or "system benefits charges" on electricity sales. These funds are most common at the state level, having been created through states’ electricity restructuring or reliability legislation. Delaware’s 1999 restructuring law, for example, provides \$1.5 million annually for efficiency and renewable programmes, funded by an average 0.178 mill./kWh charge on power sales in the state.

Table 3: State Financial Incentives for Renewable Energy

State	Personal Tax	Corporate Tax	Sales Tax	Property Tax	Rebates	Grants	Loans	Industry Recruit	Leasing Programmes	Equip. Sales	Production Incentive
Alabama	1-S					1-S	1-U				
Alaska							1-S				
Arizona	2-S		1-S		1-U				1-U	1-U	
Arkansas		1-S			1-S			1-S			
California	2-S	1-S		1-S	3-S, 8-U	5-S	1-U	1-S	2-U	1-U	
Colorado	1-S	1-S									
Connecticut		2-S	1-S	1-S			1-S				
Delaware											
DC											
Florida			1-S		1-S, 2-U				1-U		
Georgia											
Hawaii	2-S	2-S	1-S		3-U		1-L				
Idaho	1-S						1-S				
Illinois				1-S	1-S	2-S		1-L			

State	Personal Tax	Corporate Tax	Sales Tax	Property Tax	Rebates	Grants	Loans	Industry Recruit	Leasing Programmes	Equip. Sales	Production Incentive
Indiana				1-S		3-S					
Iowa			2-S	3-S		1-S	3-S				
Kansas				1-S		1-S					
Kentucky											
Louisiana											
Maine											
Maryland	2-S	2-S	3-S	1-S			2-S				
Massachusetts	2-S	3-S	1-S	1-S			1-L				
Michigan						1-S					
Minnesota			2-S	1-S	1-S	1-S	2-S				
Mississippi							1-S				
Missouri		1-S					1-S				
Montana							1-S	1-S			
Nebraska	4-S	2-S		1-S			1-S				
Nevada				2-S	1-U						
New Hampshire				1-S		1-S					
New Jersey			1-S		1-S						
New Mexico											
New York	1-S	1-S			1-S, 1-U	1-S	1-S				
North Carolina	1-S	1-S		1-S				1-S			
North Dakota	1-S	1-S	1-S	2-S							
Ohio		1-S	1-S	1-S							
Oklahoma											
Oregon	1-S	1-S		1-S	2-S, 4-U		1-S, 4-U				
Pennsylvania						1-S					
Rhode Island	1-S		1-S	1-S	2-S	2-U					
South Carolina					1-U						
South Dakota				1-S							
Tennessee							1-S				
Texas		1-S		1-S	1-U		1-U	1-S		1-U	
Utah	1-S	1-S									
Vermont			1-S	1-S							
Virginia				1-S			1-S	2-S			
Washington			1-S		1-S		1-L	1-S			
West Virginia		1-S		1-S							
Wisconsin				1-S	1-U	1-S					
Wyoming								1-U	1-U		
Totals	23	18	18	27	37	21	28	9	5	4	1

Source: North Carolina Solar Center, North Carolina State University research based on information in the Database of State Incentives for Renewable Energy (DSIRE) (2001).

4.1.3 Local incentives

In addition to the already mentioned incentives local governments use many of these same financial incentives to encourage investment in photovoltaics and other renewable power. The

main difference is however, that local programmes tend to be more tailored to local circumstances and interests than state programmes. It is interesting to note that there is a coincidence between state support for renewables and local government support. Nearly all of them exist in states that offer support for renewables, such as California (at least 6 local incentive programmes), Oregon, Florida, North Carolina, Ohio, Virginia and Washington (at least 2 local incentive programmes each). A December 2000 study¹³ identified 33 local programmes offering financial incentives for renewable energy, most of which relied on grants, loans or rebates to support photovoltaics and other renewables. Some of these measures are PV-specific incentives, while others applied to broader categories of renewables that included photovoltaics. It is highly probable that many more local programmes have been established since the December 2000 study was undertaken. The actions can be divided into two main types of measures. First, Investment and Awareness with measures like Green Pricing, Education & Assistance, Green Power Purchasing or other Local Projects. The second ones are financial incentives like Grants, Rebates, Loans, Tax incentives, Green Buildings or Industrial Recruitment activities.

4.2 The US PV-Industry Roadmap

To meet the challenge of the expanding PV markets the U.S.-based PV industry has developed a PV roadmap as a guide for building their industry [15]. Their main issues were, ensuring U.S. technology ownership and implementing a sound commercialisation strategy that should yield significant benefits at minimal cost. To do so they call for “reasonable and consistent co-investment by our industry and government in research and technology development”. Despite the high investments needed, the environmental and direct economic benefits, together with the additional energy security, will by far exceed the investments.

The goal of the industry is to meet 10% of U.S. peak electricity generation capacity by 2030. Within the next 25 years the PV industry expect to employ more than 150.000 people in the US and grow to a \$15 billion industry in 2020. To reach these goals the following scenario has been developed.

In the near term

During the next 3 years, the *solar-electric industry* will deliver quality products and services into the marketplace at fair prices. The industry will emerge during this period and continue to build manufacturing capacities to meet growing demands both in the United States and in the rest of the world.

¹³ Gouchoe, S., “Local Government and Community Programs and Incentives for Renewable Energy – National Report,” North Carolina Solar Center, North Carolina State University (December 2000).

To support these efforts, the *government* at state and federal level need to ensure fair market entrance conditions for the solar-electric power industry to compete with other power players, as well as lower the barriers that hinder photovoltaics from being developed and deployed. Government oversight and implementation is required to bring about national net metering (equity in selling PV electricity to the grid at the utility retail rate), moderate residential tax credits at both the state and federal level, and manufacturing incentives (equity with other energy-product producers). In addition, standards, codes and certification, which are essential for consumer protection and acceptance have to be established.

In the mid term

Within the next 4 to 10 years, PV industry will develop the needed technical products — whether for residential and commercial distributed generation or for architectural and building-integrated PV applications. Shares of the profits have to be reinvested to ensure vitality and growth of manufacturing capacities as well as expanding the range of products to meet consumer needs. The impact on the supply of new electrical power in the United States will increase significantly and help to firmly establish PV technologies and the solar-electric industry.

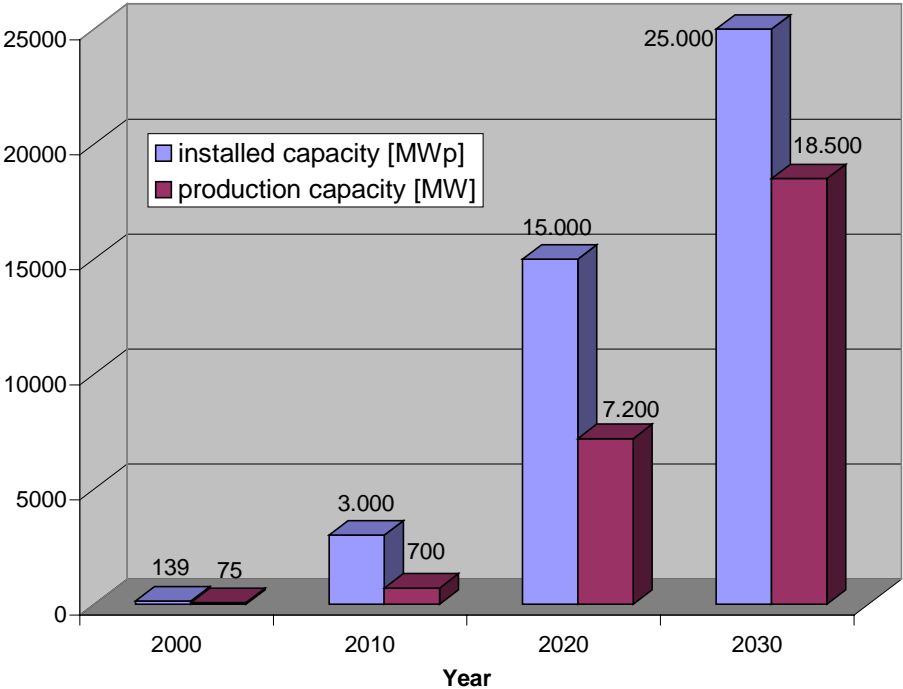


Fig. 8: US PV-Industry Roadmap [15]

In the long-term

During the next 20 years the PV industry will invest in R&D to make manufacturing lines more effective, improve production throughput and bring manufacturing to a position of world

leadership. The government is asked to continue a reasonable investment in the nation's intellectual and research resource at national laboratories, universities and other research organisations. This investment is needed to improve existing technologies and develop new and better technologies. These next-generation photovoltaic devices and products are vital for meeting future energy needs and maintaining US leadership.

A close look onto the production targets of the US PV-Industry Roadmap (Fig. 8) reveals that 70% of the production capacities are aimed for export. A strong home market like in Japan, where it accelerated the expansion of production capacities is missing in the US. This might be one of the reasons why the US lost its market leader position held for many years and is now at third place behind Japan and Europe. In addition it should be noted that four out of the five biggest US PV manufactures are owned by European companies.

4.3 Major market players

In the following most of the major market players in the US are described briefly. This listing does not claim to be complete, especially due to the fact that for some companies information or data were very fragmented. A lot of the data were collected from the companies' web-sites.

4.3.1 BP-Solar

BP Solar has its headquarter in Linthicum, MD, and after the acquisition of SOLAREX is one of the biggest PV companies with different factories world-wide. In number of sales it was number 2 in 2001 with 58 MW. BP Solar has 6 solar cell plants located in Madrid, Spain (12 MW, c-Si Saturn solar cells), Sydney-Homebush Bay, Australia (25 MW, mc-Si and c-Si Saturn solar cells) [16], Fairfield, California (2 MW CdTe-pilot Apollo line), Bangalore, India (11 MW, mc-Si), Tonano, Virginia (8 MW, a-Si) and Frederick, Maryland (20 MW mc-Si). In addition there are module manufacturing plants in Saudi Arabia and Thailand. At present the Frederick plant is BP Solar's biggest polycrystalline wafer production site with an annual capacity of approx. 35 MW/a, with a solar cell line of 20 MW/a. The rest of the wafers is shipped to Australia and India for cell manufacturing. The expansion of the wafer production to 60 MW/a capacity is under way and cell production will be expanded as well. As announced in 2001, BP-Solar will increase the production capacity of the Madrid plant to 60 MW/a [7] by 2004 and in Homebush Bay to 40 MW [17] with no date set.

4.3.2 Shell Solar

Shell Solar was established to develop commercial opportunities in solar energy. In 2001, subject to economic review, Shell committed to invest 0.5 to 1 billion \$ in solar photovoltaics (PV) and wind energy in the period from 2001 to 2006. Shell Solar recently joined the top tier

players in the solar PV industry when it integrated its business with the acquisition of Siemens Solar, a long time market leader in solar cell production. The key objective for Shell Solar is to sell solar solutions at a profit and thus meeting the criteria of sustainable development in a commercial way. To achieve this, the solar business of Shell should grow in line with the market, currently growing at around 20% - 25% a year.

Shell Solar is now active across the whole field of solar photovoltaics, from wafers production to sales to end consumer. Shell has access to both mono- and multi crystalline cell technologies and to CIS or thin film technology, the next generation of PV technology. Well-established in the manufacturing of two types of solar cells and modules, single-crystal silicon and copper indium diselenide (CIS), Shell Solar was the first company in the world to start series production of CIS solar modules. These thin-film modules boast an efficiency of over 11 percent, which is clearly higher than with competing thin-film technologies.

Shell Solar sales in 2001

Mono-crystalline modules	34.6 MW
Multi-crystalline modules	9.4 MW
CIS modules	0.4 MW
<hr/>	
Total	44.4 MW

The Shell Solar Headquarters are located in Amsterdam and Shell Solar has PV manufacturing facilities with a total yearly capacity of some 60 MW. The factory sites are in 3 countries namely:

- Ingot growing and wafers in Vancouver, WA, USA
- Mono crystalline cells and modules in Camarillo, CA, USA
- CIS thin film modules in Camarillo, CA, USA
- Multi-crystalline cells and modules in Helmond, Netherlands
- Multi-crystalline cells in Gelsenkirchen, Germany

4.3.3 Astropower

AstroPower began as a division of Astrosystems Inc., founded in 1983 as an outgrowth of semiconductor work initiated at the University of Delaware. In 1989, the company was incorporated in Delaware. The company now employs over 700 people and is currently the biggest PV-only company worldwide. Sales in 2001 were 26 MW [1].

In Spring of 2002 AstroPower had just completed the new office and manufacturing building with the first fully building integrated overhead PV system in the US. The new manufacturing lines will be APex™ solar cells featuring AstroPower's SiliconFilm™

technology and when fully operational should add another 60 MWp production capacity to the existing 26 MWp. The necessary equipment is already ordered and according to AstroPower the factory should be fully operational by the end of 2003.

AstroPower offers not only modules but complete PV systems. One of their strategic partners is “Home Depot”, the major retail chain for building products with 1300 stores all over the US. Following a successful pilot programme in San Diego in September 2001 AstroPower and Home Depot plan to expand the programme to more than 70 stores in California, Long Island (NY), New Jersey and Delaware in 2002 [18]. In addition to this retail channel AstroPower is working together with home building companies in order to realise future cost reduction of PV systems by integration of the system already in the planing phase. In some developments, all houses are already equipped with solar systems. Because the added costs are rather small and the costs are financed by a long-term interest moderate mortgage, customers prefer such developments due to the added value.

In order to secure the supply of feedstock silicon for their SiliconFilm™ technology Astropower has signed a Technical Cooperation Agreement with Elkem, the world’s largest producer of silicon metal in December 2001. Together they have developed cost-effective processes that convert quartz into feedstock for the SiliconFilm™ technology. Using this material they have reported first commercial-quality solar cells in June 2002[19].

4.3.4 ASE-Americas

ASE Americas is a subsidiary of RWE Solar GmbH (formerly Angewandte Solarenergie - ASE GmbH). RWE Solar covers three product segments of solar power technology: Wafers, solar cells and modules for the terrestrial market, thin-film solar modules based on amorphous silicon as well as high-performance solar cells for aerospace applications. In 2001, the company generated net sales of € 96 million with over 550 employees.

ASE's origins date back to 1974 when Tyco Laboratories and Mobil Corporation joined forces to begin developing advanced silicon solar cells. Although Mobil Solar Energy Corporation began selling around the world in 1981, by 1986 a strategic decision was made to focus exclusively on the U.S. utility market. In 1994, Mobil Oil Corporation decided to leave the photovoltaic industry and in July of that same year, ASE GmbH of Germany acquired 100% of Mobil's technology and assets.

ASE Americas' technology is based on a patented method called Edge-Defined, Film-Fed Growth (EFG), a process used to pull crystalline silicon octogons with a diameter of 38,5 cm and 5 m in length from growth furnaces. So far ASE Americas is mainly a material producer with a newly increased capacity of 20 MWp ribbon wafers/year [20]. It manufactures modules only with an annual capacity of approx. 5 MWp. All the other material is shipped to Alzenau, Germany, for cell production. However, with the installation of ribbon pullers in Germany, the

cell production capacities in Billerica will be expanded [21]. The equipment to process additional 10 MW is expected to be installed at the end of 2002.

4.3.5 United Solar Systems

United Solar Systems Corp. is a joint venture between Energy Conversion Devices, Inc. (ECD) and N.V. Bekaert S.A (BESS Europe), two respected technology and manufacturing companies, which formed that strategic alliance and joint venture in April 2000 to meet the growing demand for UNI-SOLAR® products. The new manufacturing plant with an annual capacity of 30MW was inaugurated on 24 June 2002 [22]. The current annual production capacity of 5MW is now being expanded to 30MW by the addition of the facility located in Auburn Hills, MI. This plant is fully automated and allows simultaneous processing of six rolls of stainless steel, each 1 1/2 miles long, during deposition of the a-Si layers. Sales in 2001 were 3.8 MW of the flexible a-Si triple junction solar cells.

4.3.6 Evergreen Solar

Evergreen Solar, founded in 1994, develops, manufactures and sells solar power products, primarily solar panels. The three markets the company serves are: wireless power, rural electrification and grid-connected applications. The company expects to exploit its proprietary and patented technology known as String Ribbon wafer production to produce distinctive products, to reduce manufacturing costs through lower materials use and streamlined processes, and to manufacture internationally for global market penetration.

In June 2001, the Company received certification and shipped its new Cedar Line (TM) series of photovoltaic modules, which incorporate 3.2-inch-wide solar cells and have a 12% conversion efficiency. The production ramp-up at the Marlboro site continues. All major equipment for the first production line (5 MWp) has been received. The Company has implemented substantial automation in the new factory.

The market situation in the US was described by Evergreen Solar as “focused on costs not on aesthetics”. This is reflected by the fact, that building integration of photovoltaics in the US has not the same importance yet as in Japan or Europe. Nevertheless, Evergreen Solar sees this as one of the most important markets in the future and has already formed strategic alliances with American companies like Solar Works, Inc. (VT) to offer solar systems in the frame of the Long Island Power Authority (LIPA) pay-down programme or Japanese companies like Kawasaki Steel for building integration of systems in Japan.

5. PV IN EUROPE

Due to the political structure in Europe with the different states and the European Union, there is no unified approach towards renewable energies yet. Despite this, the European Union has set targets within the White Paper “*Energy for the Future: Renewable sources of energy*” [23] and the Green Paper “*Towards a European strategy for the security of energy supply*” [24]. These targets are 12% of the total and 22% of the electrical energy in the European Union has to be generated from renewable energies (Fig. 9 and 10) in order to meet the obligations towards the CO₂-reduction pledged in the Kyoto Protocol and to lower the dependence on energy imports.

For this purpose, targets were set in the European Renewable Grid Directive [25] for the member states, but the European Commission left it to the member states how to reach these targets until 2006. The directive foresees that the European Commission evaluate the status in 2004 and 2006 and publishes an evaluation report at the end of October of the respective year.



Fig. 9: Share of renewable energies of total European Union electricity production.

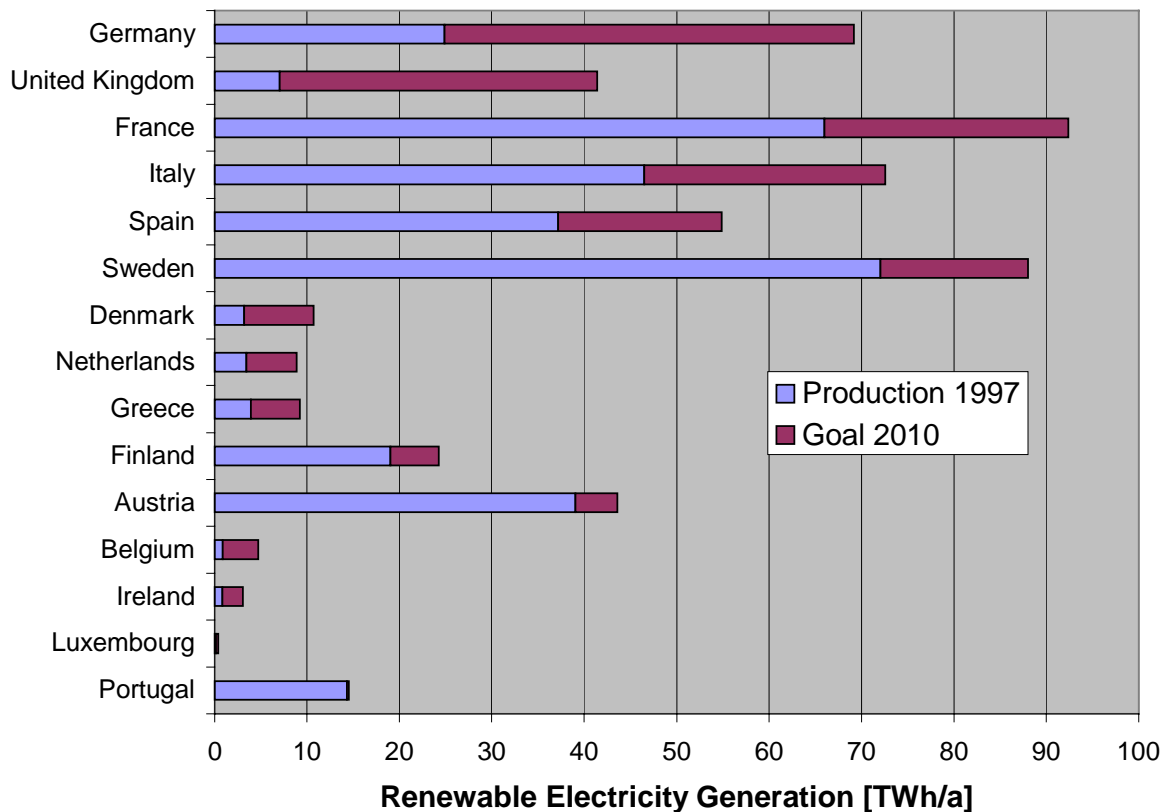


Fig. 10: Electricity generation from renewable energies in the European Union

If necessary, a common directive for the promotion of renewable energies will then be introduced after 2006. The target for the cumulative photovoltaic systems capacity installed in the European Union by 2010, is 3 000 MW or a 100-fold increase of the 1995 capacity. The electricity generation from these PV systems could then be in the order of 2.4 to 3.5 TWh depending under which climatic conditions the systems are installed.

5.1 Situation of Incentives for Photovoltaics in Europe

Similar to the US, the market conditions for photovoltaics differ quite a lot from country to country. This is due to the different public support programmes for renewable energies and especially photovoltaics as well as the different grade of liberalisation of the electricity markets. After the end of the “1000-roof programme” in Germany at the end of the 90s one could observe a shift in the investment activities of the big European PV-companies from Europe towards the US. The reasons for this were on the one hand side the more favourable economic frame conditions, like lower labour costs, but as well the competitive technological edge in the US. New production capacities in Europe were created only on a small scale by innovative start-up companies. One reason for this development was the missing market for PV systems in Europe. After the start of the large scale market implementation programmes in

Japan in 1997 and the dramatic increase of production capacities, there the European market picked up some momentum.

The different member states of the European Union use different market incentives to support the introduction of renewable energies and in particular photovoltaics. The following list names some of these incentives. However, this list is far from being completed due to the large number of programmes and some problems to retrieve the information, especially on local levels.

- **Austria:**

- investment subsidies (different in the different federal states)
- feed-in tariff (varies in the different federal states)
- RES target quotas

The Energy Law, ElWOG 2, went into force in 2001 and was implemented via decrees in each of the nine federal states. The state governments determine the different types of promotion strategies by designing the financial incentives and allowing voluntary approaches, like e.g. Green Tariffs. Two general types of financial incentives are used:

- Feed-in tariffs paying the supplied solar electricity per kWh.
- Investment support per kWp capacity.

The feed-in tariffs of grid-connected PV systems (GCS) vary between 10 and 74 ct./kWh, depending on the region, the system size as well as on seasonal and day/night aspects. The investment support foreseen for small GCS is limited to 4 000 EUR per kWp. As a result of the higher feed-in tariffs, the extra costs for the network operators will be compensated by an additional supplement on the customer invoices.

- **Denmark:**

- Renewable Energy Portfolio
- Solar roof Projects
- net metering

The SOL-1000 projects (launched 2001) intend to demonstrate highly visible and architectural acceptable integration of PV technology on existing single family houses. The owner of a PV system installed under this programme, receives a subsidy of about 35% of the turn-key costs. Net metering for privately owned PV systems was introduced mid 1998 and at that time for a pilot-period of four years. Work is ongoing to make this system more permanent.

- **Finland:**

- investment subsidies for demonstration projects
- "Green electricity"

Until the end of 2001, investment subsidies (up to 30%) were available only to communities, organisations and enterprises. For 2002 the following changes are planned: The

subsidy level will rise up to 40% and subsidies for PV systems will be made available to private persons.

- **France:**
 - Tax Exemption Law in the overseas departments
 - investment subsidies for isolated sites
 - feed-in tariff

The main sources of public financing for the installation of photovoltaic systems, are primarily the FACÉ fund and the Tax Exemption Law in the overseas departments. In addition, there are complementary supports provided by the regional authorities, the Agence de l'Environnement et de la Maîtrise de l'Énergie (ADEME), the European Commission and EDF (isolated sites in "urban scheme" which includes a subsidy lower or equal to 40 % of the cost of the system installed). The subsidy granted by the FACÉ fund is equal to 70 % of the cost of the PV system installed.

ADEME prepared an aid system aiming at the dissemination of grid-connected photovoltaic systems. This system should be operational in 2002 and photovoltaic systems will be the subject of two types of support granted by ADEME:

- Support of selected projects within the framework of European tenders up to 4.6 €/Wp (basic grid-connected PV system) and 6.1 €/Wp (grid-connected with safety storage).
- Subsidy, in the absence of European Commission funding on tenders, equal to 4.6 €/Wp, which could be increased to 6.1 €/Wp in the case of a grid-connected PV system with safety storage.

The figures given include all public subsidies. In mainland France, these aid rates will decrease as of 1 January 2005, at 3.8 €/Wp (basic grid-connected) and 4.9 €/Wp in the case of grid-connected PV systems with safety storage. A power ceiling will be applied of 5 kW for individuals and 30 kW in the community/tertiary sector.

The Ministre de l'Industrie et du Commerce finally published a 0.15 €/kWh PV feed-in tariff on 13 March 2002. The scheme will cover residential systems up to 5 kW, non-building systems (such as noise barriers) up to 150 kW, and commercial and public buildings up to 1 MW and is guaranteed for 20 years. The tariff has a double value of 0.30 € for installations in Corsica and in the overseas departments. However ADEME has only budgeted 1 MW for each of the programme's three years. In addition to the mainland target, rebates for overseas departments are available for 1 MW in the first year, 2 MW in the second and 3 MW in the third.

- **Germany:**
 - 100 000 – Roof Programme (interest reduced loan)
 - Renewable Energy Sources Act (feed-in tariff)
 - investment subsidy of various federal states

A decisive change came with the introduction of the German Renewable Energy Sources Act “Erneuerbare Energien Gesetzes (EEG)” in 2000 [26]. This Act guarantees a cost-covering feed in tariff for 20 years of currently 48 ct./kWh for PV generated electricity. Every year this guaranteed feed in tariff is reduced by 5% for new PV systems in order to put pressure on the reduction of the price for PV systems. In addition, the Kreditanstalt für Wiederaufbau (KfW), a public bank, gives loans with reduced interest rates to buyers of PV systems under the so-called 100 000-roof programme. With this mechanisms a market for PV systems was generated. Due to the EEG Act, PV systems with a total of 75 MWp were installed in Germany in 2001. This is equivalent to approximately 20% of the world market and makes Germany the biggest net importer of solar cells and modules, due to the not existing own production capacities. The new production facilities of RWE Solar and Deutsche Cell GmbH might ease this situation. Up to 30 August 2002, the KfW has reported new loans for 41 MW PV systems for 2002 [27].

For the revision of the Renewable Energy Sources Act in 2004, one can only hope that the subtle platelet of the emerging PV market in Germany will not be dried up. As the 100 000-roof programme is scheduled to finish at the end of 2003, the feed in tariff is all the more important to continue the increase of PV installations. The intention should be a smooth transition from the current subsidised PV-market into a self-sustaining market. The necessary prerequisite of lower prices for PV systems can only be achieved if the production is increased continuously. However, this will only happen if investors see a secured and long-term return on investment.

- **Italy:**
 - feed in tariff
 - 10 000 – Roof Programme (different investment subsidies in the different Regions)

The 10 000 rooftop programme is devoted to the realisation of grid-connected photovoltaic systems, ranging from 1 kWp to 20 kWp and preferably integrated in building structures. The purpose is to promote a wide diffusion of building integrated photovoltaic applications all over Italy and to create a sure and lasting market, in order to allow companies long-term investment planning. In addition, some long-term benefits are expected concerning a decrease of photovoltaic costs, the creation of job opportunities and the local development in unfavoured regions. There are two Sub-programmes:

- The first one, funded by about 10.3 mill. € is managed by the Ministry of Environment, and is addressed only to Public bodies, such as Local Authorities, Universities and Research Institutions.
- The second one, addressed also to citizens and private companies, is composed of 21 local Programmes. The nineteen Italian Regions and the two Autonomous Provinces of Trento and Bolzano have agreed to jointly fund the initiative, providing in total 9.3 mill. € or

about 30% of the total public incentives. The remaining 70% (i.e. 20.7 mill. €) are still funded by the Ministry of Environment. Ministerial funds have been shared proportionally among participants with their populations.

In general, contributions of up to 75% of the eligible investment cost can be provided by both Sub-programmes. The maximum investment cost has been fixed at about 8 €/Wp, for photovoltaic plants ranging from 1 to 5 kWp. In the range from 5 to 20 kWp, the maximum investment cost is decreasing to 7 €/Wp.

- **The Netherlands:**
 - Renewable Energy Portfolio
 - investment subsidies
 - green tariffs

Since 1 January, 2001, PV together with Solar Domestic Hot Water (SDHW)-systems and heat-pump boilers, are on the Energy Premium Regulation (EPR) products list. This EPR is meant for house-owners (including housing corporations) who invest in improving their houses energy-wise. The amount of subsidy for PV in 2002 is 3,50 €/Wp, which can be obtained by filling in a simple form with a copy of the receipt. The subsidy can even be increased by 25% when an EPA, an Energy Performance Assessment, of the house is done.

Utilities like NUON and Eneco Energie have published subsidies of around 1 €/Wp in their service area, due to the importance of the positive image of solar energy in the liberalised green energy market.

- **Portugal**
 - feed in tariff (Decree-Law 2001)
 - grants for investments

A new (revised) legislation promoting renewable electricity was introduced in the framework of the 2001 E4 Programme. The tariff rates are now differentiated by technology, allowing not only for increasing penetration of consolidated technologies (wind, mini-hydro), but also for developing projects relying on emerging technologies with high potential in the medium run (e.g. biomass, wave and photovoltaics). In particular, the new buy-back rates for PV are 0.28 €/kWh (> 5 kWp) and 0.50 €/kWh (< 5 kWp), which are considerably higher than the former tariff (0.06 €/kWh).

Financial incentives for renewables and energy efficiency applications are available under the POE programme (2000-2006) – III EC Framework Programme. Grants are provided on the basis of energy and environmental value of the projects, typically ranging from 20% to 40% of the total eligible costs.

- **Spain:**
 - investment subsidies (several Spanish Autonomous Regions)
 - feed in tariff (Royal Decree 2818/1998)

Several Spanish Autonomous Regions have developed programmes to support renewable energies. PV installations, both off-grid and grid connected, are subsidised with about 30-35% of the total installation cost.

The Royal Decree 2818/1998 provides an advantageous feed-in tariff for every kWh produced by photovoltaic systems connected to grid. Utilities must buy photovoltaic electricity at 0.40 €/kWh for systems of less than 5 kWp and at 0.20 €/kWh for systems with more than 5 kWp. This sort of measures, together with a major knowledge and acceptance of photovoltaic energy on the part of the public, have contributed to the constant growth of photovoltaic sector in recent years.

- **Switzerland:**
 - feed in tariff (different from Canton to Canton)
 - green tariffs (different from utility to utility)
 - investment subsidies (different from Canton to Canton)

The market implementation of PV systems is driven by the campaign for "solar electricity from the utility." At the end of 2001, more than 130 utilities (1996: 7) offered solar electricity to their customers. Different financial models are being used according to the preferences of the utilities. Meanwhile, more than 50% of the Swiss population have access to solar electricity and more than 30 000 customers annually use about 4 GWh of renewable energy.

The introduction of the labels "naturemade basic®" and "naturemade star®" for green power products (www.naturemade.ch), promotes green power produced by different technologies. The "nature made star®" label, promises that 2.5% of the total energy delivered is from new renewable energies (photovoltaics, wind, biomass). Using these labels, green electricity is now also promoted as part of the SwissEnergy programme.

- **United Kingdom:**
 - investment subsidies (so far only demonstration projects)
 - investment grants

The Major PV Demonstration Programme was launched in the first quarter of 2002. This is the first phase of a potential 10 year programme. GBP 20 million funding has been allocated for the first phase (3 years). The programme provides capital grants for the installation of domestic and non-domestic PV systems in the public and private sectors.

5.2 PV Research and Market in Europe

In addition to the national programmes for market implementation, research and development, the European Union funds research (DG RTD) and demonstration projects (DG

TREN) with the Research Framework Programmes since 1980. Compared to the combined national budgets the EU budget is rather small, but it plays an important role in creating a European Photovoltaic Research Area. This is of particular interest and importance as the European PV industry is much more fragmented than their competitors in the US and Japan (Fig. 11).

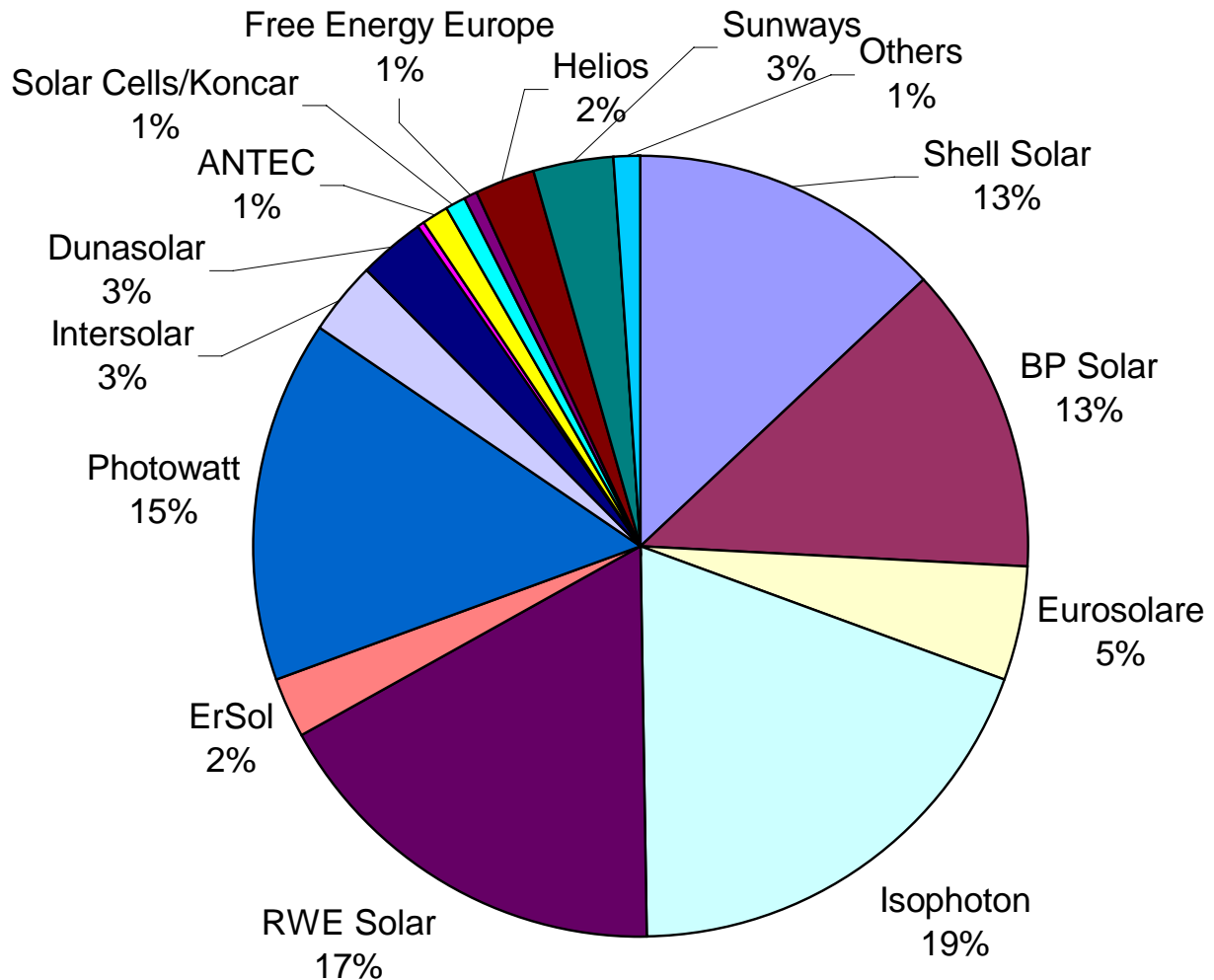


Fig. 11: Market shares of the European PV companies (2001: 93.7 MW, this corresponds to 23.6% of the world-wide sales) [1]

Besides the conventional silicon solar cell technology a number of activities towards the commercialisation of thin film solar cells are under way in Europe. After Japanese companies having taken the lead in the field of amorphous solar cells, European researchers are trying to narrow the gap through new innovative developments. A field of particular interest is the combination of amorphous and nano/microcrystalline silicon to form a a-Si/ μ -Si tandem solar cell. This concept promises a higher and more stable conversion efficiency. During a European workshop on “Cross-Fertilisation between the Photovoltaic Industry & other

Technologies” at the Joint Research Centre in Ispra an interesting and promising new production technology for this type of solar cell was presented by UNAXIS. The technology is based on the classical production technology for flat panel displays and was adopted for solar cell production [28]. There is hope that such new production technologies will contribute to a big increase in production capacities in Europe in the near future.

Similar evolutions can be observed in the area of compound semiconductor solar cells (CdTe, Cu(In,Ga)(S,Se)₂). Despite the fact that two of them have their production in the US, all four companies, which are, even with small quantities, in the market are European companies. These companies are followed by about 15 additional start-up activities worldwide with the majority in Europe. Quite a number of these activities was or is supported by the European Commission, albeit it is not yet possible to support the development and installation of pilot plants on a European level.

The continuous expansion of the production capacities for solar cells is of particular importance in light of the export markets for solar systems to the rural areas in Asia, Africa and South America, where more than 2 billion people are still without electricity. The Europeans should not lose this future market, also with respect to the possibility it offers for the labour market. In October 2001 the European Photovoltaic Industry Association (EPIA) and Greenpeace presented a joint study, which estimates that the solar electricity industry in the European Union will create approximately 290 000 new jobs by the year 2020 [29]. To reach this goal it is estimated that solar electricity capacities of 54 MW will be installed in the European Union by 2020, which is very ambiguous. Under the more conservative estimate that the European Union will reach the White Paper goal of 3 GW in 2010 and that the installation of PV systems growth by 17% the years after, 15 GW installed capacity would be reached in 2020. Even this would mean 20 000 new jobs by 2010 and 50 000 by 2020.

A prerequisite for all such developments is that parallel to the public market introduction incentives that electricity generated by solar systems can be freely traded and get preference grid access. As PV systems contribute to the avoidance of climatically harmful greenhouse gases, electricity generated from solar systems has to be exempted from eco taxes where applicable. In addition it has to be ensured that PV system operators can sell green certificates to CO₂-producers.

5.3 Major market players

In the following, most of the major market players in Europe are described briefly. This listing does not claim to be complete, especially due to the fact that information or data for some companies is very fragmented. A lot of the data were collected from the companies' web-sites. Despite the fact that BP Solar and Shell Solar are European companies, they were already listed in Chapter 4.3 because their biggest operations are still there.

5.3.1 Isofotón

Isofotón, a private owned company, was set up in Malaga to produce silicon solar cells by Professor D. Antonio Luque from the Universidad Politécnica de Madrid. In 1985, Isofotón expanded their activities in the solar sector and started to fabricate solar collectors as well. With growth rates above average, Isofoton has become the largest manufacturer of solar cells in Europe (18 MW in 2001). About 80% of the production is exported, with Germany as the biggest market. The production capacity in 2002 is 36 MW and it is planned to expand it to 70 MW by 2004.

To be present in a developing market in South Africa, Isofotón Southern Africa, an 80% subsidiary, started its operation in December 2002. To strengthen its market position in Germany a 20 MW module factory is also planned.

Besides silicon solar cells and modules, Isofotón is very active to develop flat-panel concentrator systems based on GaAs solar cells. This kind of system is favourable for areas with a high proportion of direct sunlight and for large-scale solar plants.

5.3.2 RWE Solar

RWE Solar GmbH, Alzenau (Germany), is a subsidiary of RWE Solutions AG, Frankfurt am Main. It has four divisions: RWE headquarters in Alzenau. The Space Solar Cells Division in Heilbronn, the Phototronics Division in Putzbrunn and ASE Americas (see Chapter 4.3). In 2001, RWE Solar had sales of 21 MW with ASE Americas accounting for 5 MW.

Solar cell development started at the Space Solar Cells Division as long ago as 1964, initially for space and then also for terrestrial applications. In 1994 the company was integrated into ASE via Daimler-Benz Aerospace. This merged many years of experience in the development for high power and space solar cells by the previous companies, Telefunken and AEG.

Development of amorphous silicon solar cells started at MBB in 1980. Phototronics (PST) was founded in 1988. In 1991 one of the world's first large-area pilot production facilities for amorphous silicon was built.

The photovoltaic activities in Alzenau started in 1979 with NUKEM initially developing thin-film technologies. In 1986 they developed crystalline silicon solar cells and cast-resin large-format modules and started a pilot production. 2002 RWE Solar GmbH opened the fully automated production lines for solar cells with a capacity of 20 MW using their world-wide patented EFG silicon. In addition to the fabrication of solar cells, the plant will also produce EFG wafers. When running at full capacity in the year 2004, the fabrication plant is planned to produce 60 MW solar cells annually.

5.3.3 Photowatt

Photowatt was set up in 1979 and relocated to Bourgoin-Jallieu in 1991, where the company converts silicon waste into the raw material used for the manufacturing of solar energy cells. At the beginning of 1997, Matrix Solar Technologies, a subsidiary of the Canadian company ATS (Automation Tooling Systems), acquired Photowatt International and started to expand the production capacities. Matrix Solar Technologies used its marketing and management expertise, with the twin objectives of assisting the growth and reinforcing the position of Photowatt International in the world market, by facilitating its presence in new countries. This is particularly true in the Cape, in South Africa, where Photowatt is involved in a joint-venture technology transfer, installing and starting up an assembly unit. Other countries are presently being studied for such operations. In 2001 Photowatt had sales of 14 MW.

5.3.4 Eurosolare

Eurosolare S.p.A., is a subsidiary of Eni SpA. The company has been in the photovoltaic business since the early '80s and is the only Italian industry to operate with a vertically integrated cycle, from raw material to systems. Eurosolare produces standard mono and multi-crystalline PV modules with sales of 4 MW in 2001.

6. OUTLOOK

Four of the 10 biggest solar cell manufacturers are from Japan, with the No 1 and 3 for 2001 (Sharp and Kyocera). Mitsubishi Electric has advanced to the top 10 companies with 14 MW sales in 2001 and its sister company, Mitsubishi Heavy started its production line of amorphous silicon solar cells in autumn 2002 with an initial capacity of 10 MW. After the impressive increase of 60% in 2000, the Japanese companies could increase their sales in 2001 by further a 46%. Despite the fact that the European companies similarly increased their output, one has to bear in mind that they started from a lower level. The US companies, however, lost market shares due to lower growth rates in production capacities. For 2002 it can already be appraised that Europe will advance to the 2nd place.

The continuous and consistent support for photovoltaics in Japan has made it possible that the ambiguous goal of 1994 to install 200 MWp of PV systems in 2000 was reached with only one year delay in 2001. The long-term strategy until 2010 is another reason why the Japanese photovoltaic industry has advanced within only 10 years, to take the market lead. Despite the difficult economic situation, a further increase in production capacities for solar cells can be expected in Japan. The reason for this is the fact that the Japanese industry sees PV manufacturing as a “key industry” at the beginning of the 21st century. This shift in the evaluation of future perspectives of the PV industry has resulted in the fact that traditional heavy industry companies like Mitsubishi Heavy have started a solar cell business. There are reports about solar cell research activities of other companies as well, e.g. Honda [30] or Sumitomo Electric Industries [31], but so far, no concrete business models have been released.

Before the start of the Japanese market implementation programme in 1997, annual growth rates of the PV markets were in the range of 10%, mainly driven by communication, industrial and stand-alone systems. In the last five years the PV market now has grown by 30% annually and reached a volume of 400 MW or 2.5 bill \$ in 2001. Despite the current economic slow down the future for PV in Japan, Europe and the US seems still to be bright. According to information given by METI in February 2002 there were signs of recovery for the Japanese home construction market, which is an important distribution channel for new PV systems. This assessment of the market seems to be backed by the newest figures for new PV installations in Japan. From April to 6 September 2002, more than 15 900 new applications for PV systems were received by NEF [32]. However, to what extent the FY2002 target of 230 MW new installed solar electrical generation capacity can be reached, is not clear yet.

Also in Germany, the PV market seems that it will recover from its weakness at the beginning of this year. At the end of August the KfW has approved interest reduced loans for new PV systems with a total volume of 41.4 MWp [33]. This is about 55% of last year’s new installed solar electrical capacity in Germany. This development, as well as the increase of the

350 MWp cap to 1 000 MWp for the support of new solar systems by the financial committee of the German Bundestag at the beginning of June [34], too indicates a continuous future demand for PV systems.

The rising number of market implementation programmes in other European Countries, e.g. Italy (10 000 roofs programme), United Kingdom (Major Photovoltaic Demonstration Project), as well as the different regional incentive programmes in the US, contribute to keeping the demand for solar systems high. In the long-term the growth rates for photovoltaics will continue to be high, even if the economic frame conditions can lead to a short-term slow down of the growth rates. In the run up to the UN Johannesburg Summit for Sustainable Development in August 2002, the president of BP Solar, Mr. Harry Shimp, declared in an interview with Reuters: “Ultimately the world has to move toward renewable power. In 20-25 years the reserves of liquid hydrocarbons are beginning to go down so we have this window of time to convert over to renewables.” [35]. These remarks are in line with the energy scenario of the oil company Royal Dutch/Shell, which predicts high growth rates for renewable energies in the coming decades [36].

Figure 12 shows the world-wide potential of the renewable energies, mainly geothermal and solar, which is sufficient to supply a world population of 10 billion people with approx. 300 GJ of energy per capita. Solely Europe and Asia, whose potential is only 100 GJ/capita, would be required to import energy.

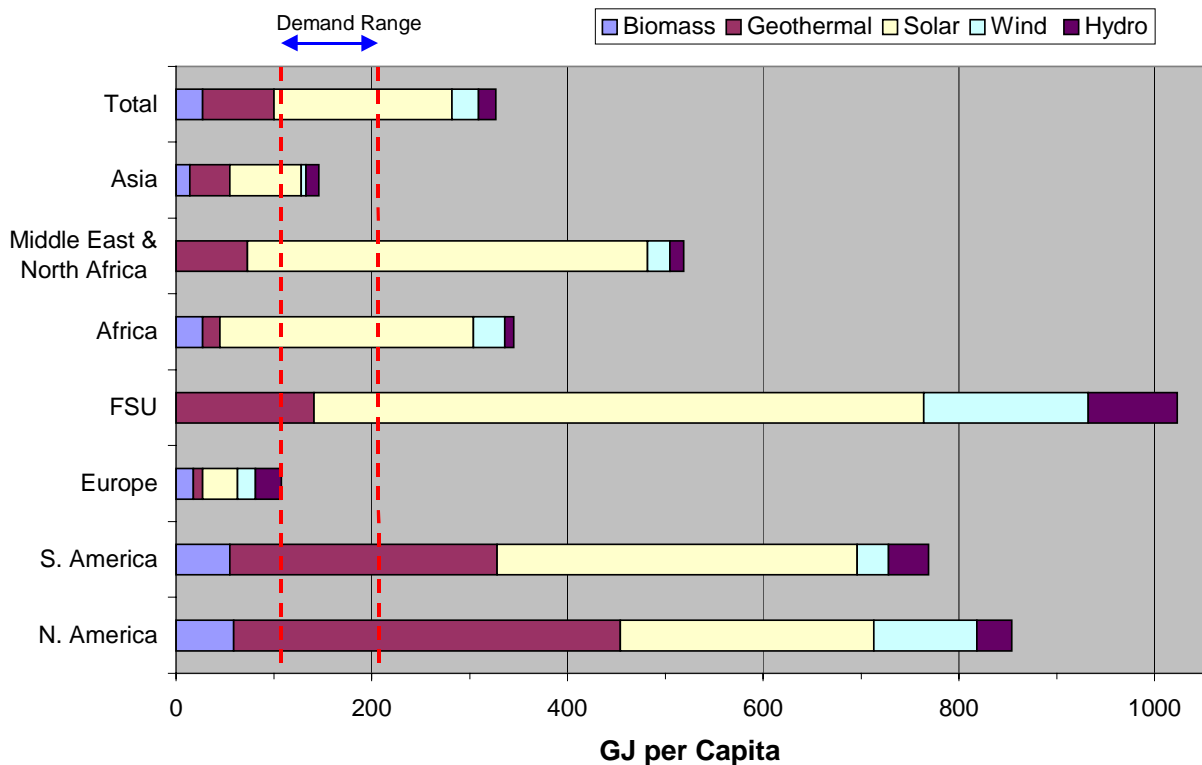


Fig 11: Potential of usable renewable energies calculated for a world population of 10 billion people [36]

Despite the fact that the Johannesburg Summit could not agree on the binding target of 15% renewable energies by 2010, the resolution passed is an important step forward. The Summit made a commitment to: “Increase access to modern energy services, increase energy efficiency and to increase the use of renewable energy.” and “To phase out, where appropriate, energy subsidies” [37]. At the same time, the European Union announced a \$700 million partnership initiative on (renewable) energy and the United States announced that it would invest up to \$43 million in 2003.

According to bank analysts and prognoses by industry, solar energy will continue to grow at high growth rates in the coming years. Figure 13 and Table 4 show the different projections of the Japanese, US and EPIA roadmaps.

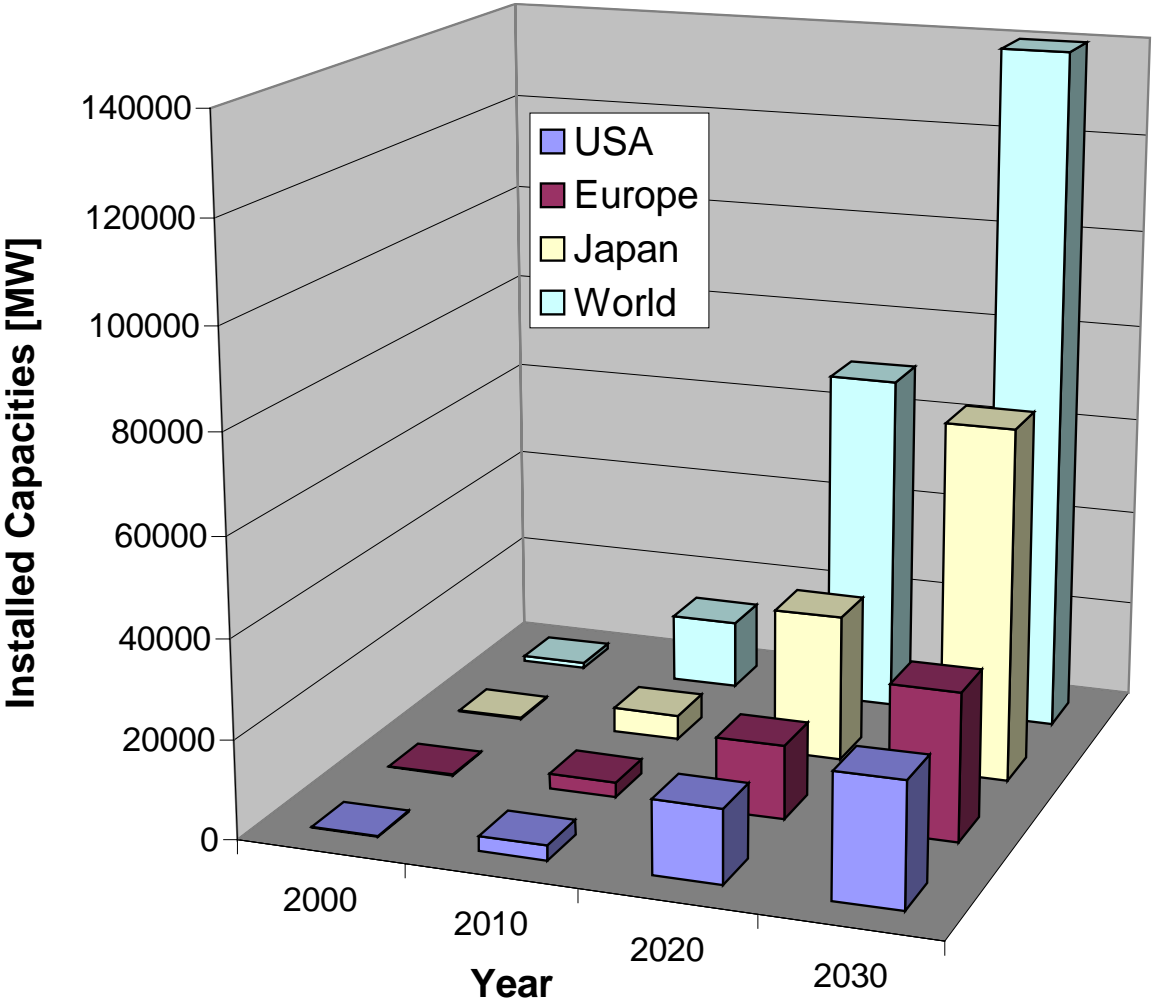


Fig. 13: Evolution of the solar electrical capacities till 2030
(Sources: Japanese, US and EPIA Roadmap)

Tab. 4: **Evolution of the solar electrical capacities until 2030**
 (Sources: Japanese, US and EPIA Roadmap)

Year	2000	2010	2020	2030
USA [MW]	140	3.000	15.000	25.000
Europe [MW]	150	3.000	15.000	30.000
Japan [MW]	250	5.000	30.000	72.000
World-wide[MW]	1.000	14.000	70.000	140.000

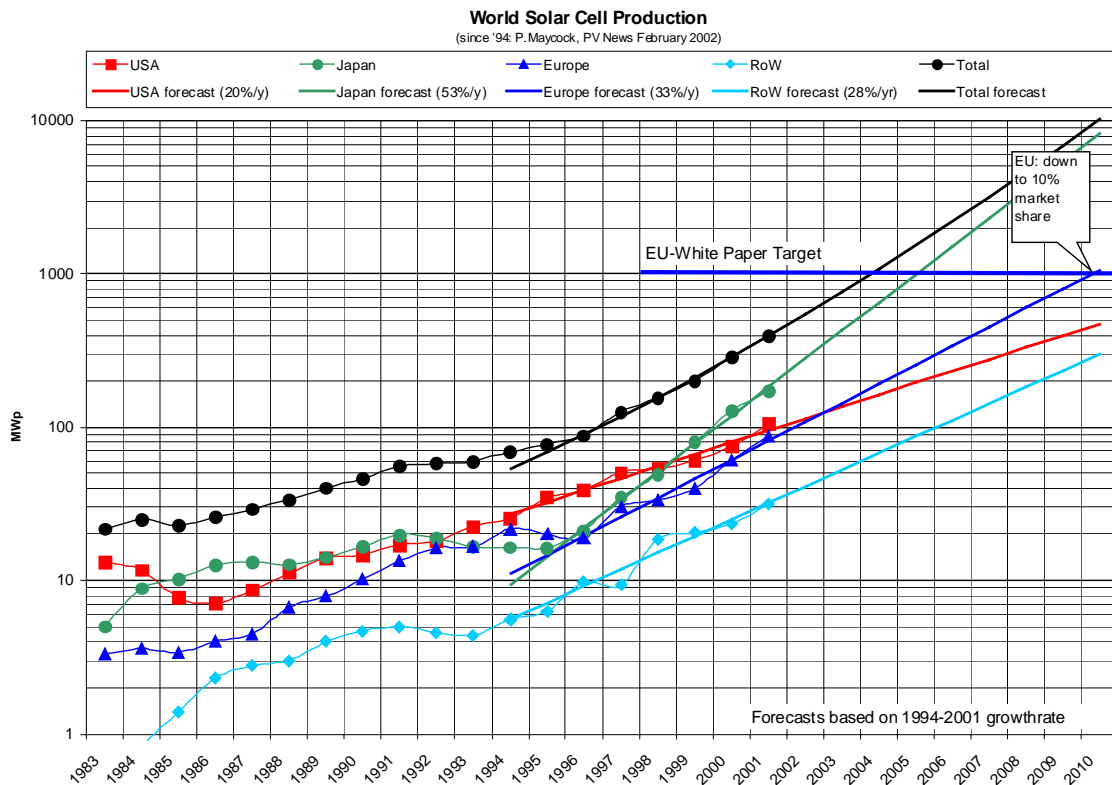


Fig. 14: Extrapolated increase of production capacities until 2010 using the growth rates since 1994

At present the photovoltaic industry is in the process to leave its infancy and become a fully-fledged mass-producing industry. This development is connected with the current process of concentration and acquisition of competitors. This development is a risk and a chance at the same time. If the new large solar cell companies use their cost advantages to offer lower priced products customers will buy more solar systems and it is expected that the PV market will show an accelerated growth rate. However, this development will influence the competitiveness of small and medium companies as well. To survive the price pressure of the big companies made possible by the economics of scale of large production volumes, they have to specialise in niche markets with a high value added to their products. The other possibility is to offer technologically more advanced and cheaper solar cell concepts.

Europe is on track to fulfil its own – even when not very ambitious – targets for 2010. However, should the current trend in the field of production capacity increase continue in Japan, the US and Europe and no additional endeavours are made in Europe to change this, then Japan will dominate the PV world-market in 2010 with over 75% of the market share (Fig. 14).

7. ACKNOWLEDGEMENT

This report is based on visits to Japan and the US in the spring of 2002, where government entities, research centres and the leading industry companies were visited. I would like to thank all my hosts for their kindness and the time they took to receive me, to share their knowledge and to discuss about the status and prospects of photovoltaics.

In order of visit:

Japan: Delegation of the European Commission in Japan; METI: Ministry of Economics Trade and Industry (New and Renewable Energy Division, Energy Conservation and Renewable Energy Department, Agency of Natural Resources and Energy (ANRE)); NEDO: New Energy and Industrial Technology Development Organisation; CRIEPI (Central Research Institute of Electrical Power Industry); Sekisui Chemical Co., Ltd.; PVTEC: Photovoltaic Power Generation Technology Research Association; Mitsubishi Heavy Industries, Ltd.; Tokyo Institute of Technology; NEF: New Energy Foundation; Shinshu Daigaku, Nagano; Kaneka Solartech Corporation; SANYO Electric Company; Sharp Corporation; Toyota Technology Institute, Semiconductor Lab; Nagoya; Yazaki Corporation

USA: Evergreen Solar; ASE Americas; Energy Photovoltaics Inc.; BP Solar, Frederick; Solar Electric Power Association; Department of Energy; Delegation of the European Commission in the US; ASTROPOWER

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