DRIVING THE PV INDUSTRY TOWARDS COMPETITIVENSS

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ABSTRACT: The PV industry is currently experiencing very high growth rates and it is generally assumed that this will continue through to 2010. Based on a bottom-up analysis of the possible Si wafer based and thin film module production in 2010, a production volume of 11 GW is estimated. The amount of electricity generated from the accumulated installed PV modules by 2010 will be less than 30 TWh, or less than 0.15% of the total electricity generated in that year. To move the PV industry out of its niche existence, it is necessary to reach grid parity, at which stage the enormous electricity market independent from government incentive programs would open up. This market position can be reached when the current system price is reduced by over 40%. It will be argued that this cost reduction can be achieved by a range of technology platforms. Since the overriding aim of the PV industry is to drive solar electricity to cost competitiveness, the industry is challenged to commercialise all of those technologies, which have the clear potential of halving the current system costs. The gain for those technologies that first reach grid parity and thereby are pulled into the global electricity market on a cost competitive basis is extremely high.
Keywords: Cost reduction, Economic analysis

1 INTRODUCTION

The photovoltaic (PV) industry currently experiences a tremendous year on year growth exceeding 30%. These growth rates could give the impression that PV is on the verge of leaving its niche existence and establishing itself as a main electricity source in the near future. This paper will take a look at the growth rates from today until 2010 to estimate the production of PV modules in that year. The electricity that could be generated by the accumulated installed PV modules is then set into perspective to the overall electricity industry. It will be shown that despite these ambitious growth rates over the next several years, PV will contribute less than 0.15% of the overall electricity generated in 2010. It will be argued in this paper that if the PV industry is aiming to achieve a noticeable share of the global electricity generation, system costs and prices will have to be reduced significantly by over 40% within the next few years. Only when such a price reduction is achieved, the enormous electricity market independent from government incentive programs will open up.

2 METHODOLOGY

2.1 Market analysis

To project the production of PV electricity generated by the year of 2010, the production of PV generators was segmented into three areas: (i) Si-wafer based (ii) thin-film and (iii) other technology platforms. For each segment the publicly available announcements combined with information provided directly from the players in the various segments was analysed to build up a year by year projection of the production of PV modules. This projection was then weighted with probability factors, based on in-house expertise and discussions with out-side experts in the respective fields, expressing the likelihood that the announced production volumes will actually be achieved.

2.2 Cost analysis

A range of PV technology platforms was selected for the cost analysis. The selection criteria were the "readiness" of a technology to be commercialized in the medium-term future. Any selected technology had to be in a position that it could, in principle, contribute a noticeable share to the overall PV module production by 2010. For each technology platform a hypothetical large-scale, well operated production facility was analyzed. The standardized size of a facility was about 100 MW, assuming that cost-inefficiencies of under-sized facilities would be avoided at this production size and a level-playing field would be ensured. For each technology, the direct material and labour costs as well as indirect costs were estimated in addition to the investment costs. The productivity of the facilities was set taking technology specifics into consideration to again create a level playing field. The costs were compared on a system level basis taking into account the differences in balance of system costs (BOS costs) related to the area dependent share of the BOS costs, which tend to scale anti-proportional with efficiency of the PV modules.

The PV technology platforms analysed for this study were (i) the Si wafer based technologies including multi Si, mono-Si and string ribbon Si (combined under "mc-Si"), (ii) Si thin-film technologies including the approaches of crystalline thin film silicon and micromorph silicon on glass (combined under "TF-Si on glass"), (iii) silicon thin-film roll-to-roll production ("Si TF on flexible"), which was analysed separate to rigid Si thin film due to its potential of achieving reduced BOS costs, (iv) CdTe and (v) CIGS. Concentrator systems were not included in this study. Their potential has to be compared on a cost per kWh, rather than on a system costs per installed kWp basis.

3 RESULTS

3.1 Market analysis

The production of Si wafer based PV is determined by the availability of poly-Si. The actual production of

Generation Technology	Typical Power	Generation per Year	Invest per Power	Invest per Generation	Generation Cost (c=€c)	Comment to the Generation Cost*
Nuclear	1500 MW	12 TWh	0.8-1.6 €/W	0.1-0.2 €/kWh	1.5-2.5 c/kWh	Capital cost ~50% of total
Coal	500 MW	3.5 TWh	0.8-1.2 €/W	0.1-0.15 €/kWh	2-4 c/kWh	Capital~ 35%, fuel ~45%
Gas	250 MW	1.5 TWh	0.3-0.6 €/W	0.04-0.08 €/kWh	3-5 c/kWh	Fuel ~80% of total
Wind	100 MW	0.5 TWh	0.8-1.6 €/W	0.3-0.6 €/kWh	3-7 c/kWh	Strongly site dependent
Solar (2005)	1 MWp	0.001 TWh	4-7 €/W	3-6 €/kWh	30-60 c/kWh	Strongly site dependent

Table II: Comparison of investment costs. Numbers for Nuclear, Coal, Gas and Wind are based on Ref. 4.

poly-Si in 2010 is hazed with numerous uncertainties. Besides the uncertainty whether announced capacities will actually be built in time or will be built at all, an additional, important uncertainty is the advent of alternative production routes like direct refinement of metallurgical silicon. Considering these uncertainties a range of about 65 kMT (thousand metric tones) to almost 100 kMT is estimated. The authors see a poly-Si production of 80 to 90 kMT in 2010 as feasible. As for the share of poly-Si available for the PV industry, a demand of 25.5 kMT for the electronic industry and a conversion rate of 6.5 g/W_p can be seen as realistic values in 2010. Combining these factors, a Si wafer based PV production of 9 GW seems possible.

In terms of thin-film solar module production a similar approach was chosen. The announced expansion plans for the various thin-film technologies were collated leading to a combined production of over 3 GW. Weighting these announced production volumes with the probability factors, two thirds of the total volume appeared to be realistic, bringing the thin film module production to about 2 GW.

Besides the traditional Si wafer based and thin film PV production, other solar energy concepts like low and high concentrators are like to reach maturity until 2010. The authors, however, estimate that the annual production will only reach some 100 MW by the year 2010.

3.2 PV from an electricity industry perspective

The combined PV power generator production in 2010 could, therefore, exceed 11 GW. This volume would imply a six fold increase of production compared to the year 2005. Despite this tremendous growth solar electricity will remain negligible from an electricity industry perspective. As illustrated in Table I, the total electricity generated from the accumulated installed PV power by 2010 could sum up to 29 TWh compared to 20,300 TWh of total electricity produced in the same year. Solar electricity, therefore, will account for less than 0.15%.

Table I: Comparison of electricity production in 2004 and 2010. Numbers for the electricity industry are based on Refs. 1-3.

	Unit	2004	Trend	2010
Cum. Capacity	GW	4,100	2.5% pa	4,800
Cum. PV	GW	3	45% pa	28
El. Generation	TWh	17,500	2.5% pa	20,300
PV electr. Gen.	TWh	2.5	50% pa	29

Table II compares the technology specific investment cost scaled to a typical power plant size for respective technology. The investment costs per electricity generation capacity per annum is for PV more than 30 times the equivalent cost for coal or nuclear power stations. The importance of the investment cost is underlined by fact that a large fraction of investment in new base electricity generation capacity goes into gas stations, although this technology due to the high fuel costs in most cases yields higher generation costs per kWh than nuclear and coal [4]. This comparison shows the investment hurdles PV still has to overcome from an electricity industry perspective. Consequently, looking at PV through an electricity industry lens, solar electricity still seems to have a very long way to go. The intermediate target of the PV industry is, therefore, not the direct competitiveness with electricity generation costs of the traditional technologies, but to compete with electricity prices at the consumer level. The end customer has to weigh his or her opportunity cost of electricity with the cost of electricity generated by a PV system.

3.3 PV technology cost comparison

Figure 1 shows the results of the analysis of the selected PV technology platforms. The system costs are standardized to the current mc-Si system costs. The comparison shows that all analysed technologies have the potential to lead to a significant reduction of the overall system costs.

(i) *mc-Si:* A combination of best practice along every step of the value chain and technological improvement particularly with regard to efficiency, wafer thickness and productivity can lead to a reduction of over 50%.

(ii) *TF-Si on glass*: This technology platform has the potential of reducing overall system costs compared to today's cost by 30 to 60%. The key for success is to realize higher efficiency, increase productivity, and take advantage of economy of scale.

(iii) *TF-Si on flexible:* On one hand Si thin-film technologies have the potential of reaching even lower system costs than TF Si on glass. This is primarily due to the fact that Si thin film modules on light weight, flexible substrates can be incorporated in building components such as roof membranes, which can significantly reduce the BOS costs. On the other hand if this BOS cost reduction is not fully leveraged, the overall system costs would be even higher than the mc-Si technology. TF-Si on flexible would, however, also in this case be in the position to address market segments not accessible to heavy and rigid modules.

(iv) *CIGS and CdTe* have the potential to under cut the mc-Si technology, if the production facilities are operated on a best practice basis and their efficiency potential is realized. CIGS is particularly of interest in market segments where efficiency, due to area constraints and aesthetics matter most. CdTe has the potential to achieve overall cost leadership when comparing technologies on a rigid substrate approach.

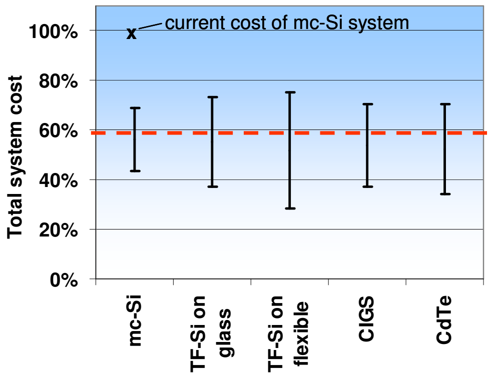

Figure 1: Comparison of projected system costs of different module technologies in 2010, referenced to the current (2006) cost of mc-Si based systems.

4 DISCUSSION

4.1 Price and demand

The current PV market is created by politically motivated incentive and support programs like the German EEG (Renewable Energy law). Due to these programs, PV is currently expanding by over 30% year on year despite typical system price of around 5€/W_p . Figure 2 shows that an annual price reduction of 5% would lead to system price of just below 4 €/Wp by 2010, an overall reduction of 23%. This price reduction would leave the PV industry still subject to government incentive programs and would not enable the PV industry to enter the electricity peak shaving market on a large scale.

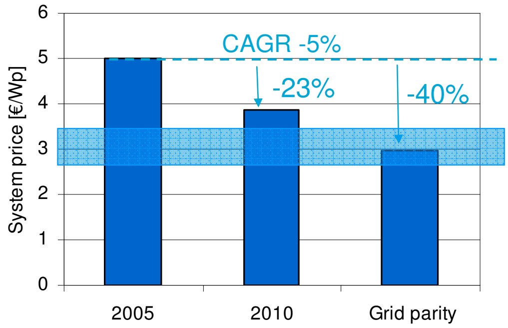

Figure 2: Current system price and scenarios for price reductions.

The grey horizontal area in Figure 2 indicates the system price range at which PV electricity generation costs begin to fall into the ranges of end customer electricity price, particularly in areas where prices vary throughout the day in line with midday peak demand. In order to ensure a much larger demand than the demand steered by the incentive programs and significantly exceeding the foreseen supply, the PV industry has to drive down the system costs by more than 10% per annum until 2010. This would lead to an overall price reduction of over 40% and total system costs below 3 €/Wp. Only then will PV be exposed the "bottom-less" surge of electricity demand created by a competitive price position of PV compared to standard electricity prices at the end customer level. Reaching grid parity is not a static well-defined threshold, but will depend on main factors such as the local irradiation, the local electricity prices, the local grid system etc.

4.2 System cost comparison

Section 4.1 revealed that a cost reduction of at least 40% has to be targeted, if the PV industry wants to grow much faster than currently projected. This target can be set in relation to the possible cost reduction analysis presented in Figure 1. All selected technology platforms have the potential to reach the target or even under cut it significantly. Figure 1, however, also shows that each technology bears the risk of not succeeding on a cost level. The addressed thin-film approaches have to prove themselves on a commercial basis against the large cost reduction potential that still lies within the Si wafer based technology. The Si wafer based technology has the potential to reduce costs even below the estimations presented here, when cells of efficiency in the range of 22% can be manufactured on a cost effective basis. There is no clear winner.

4.3 Strategic impact

On one hand there is the clear necessity to significantly reduce system price, if the PV industry wants to reach grid parity in the near future, at which point a large market independent from incentive programs would open up. On the hand there is no clear technological winner at this point of the development. The industry is, therefore, challenged to commercialise all those technologies that could drive PV to competitiveness by reaching grid parity in the medium-term future. .

5 CONCLUSION

Despite its very high growth rates, the PV industry will still remain a niche player seen from the electricity industry perspective. Tremendous growth potential is created when the solar electricity generation costs reach grid parity. The analysis presented in this paper showed that several technology platforms have the potential to lead to cost reduction of over 40% and open the door to reach grid parity. On the basis that no clear winning technology can be identified, it was argued that those, which have the cost reduction potential in the medium term future, should be aggressively commercialised.

6 ACKNOWLEDGMENT

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