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Economical and operational issues for CIGS in the future PV panorama

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ABSTRACT

Due to the low costs of multi-crystalline Si ($0.6/Wp present average, and $0.38/Wp projected by 2018), $Cu(InGa)(Se, S)_2$ (CIGS) thin film is facing a competitive environment as product needs to be aligned in efficiency, reliability and fabrication costs with main stream modules. Moreover, into the final quarter of 2016, the PV industry has been again confronted to an overcapacity panorama, which has demonstrated very harmful for manufacturers and module producers that have not been able to follow the costs reduction learning curve together with increasing in efficiency and product reliability. However, just follow the leader could not be enough, and without innovations leading to new advanced solutions to the stablished market and/or create new ones, the survival of the technology is compromised.

In this paper, an approach to the present and a projection of near future competitiveness of CIGS respect to the expected performances in conventional markets is provided. For this efficiency and manufacturing issues related with costs assumptions and bankability are discussed. An example of an industrial line targeting enough flexibility to address present and future emerging markets need is discussed. The main aim is give clues to CIGS manufacturers to develop a competitive product within the future PV panorama and to innovate not only in materials and product, but also in market and business models. At this step, innovation in products, markets, and financial issues seem mandatory for the technology to survive in a very competitive growing global market, and for this flexible manufacturing facilities with reduced costs need to be developed.

1. Introduction

To understand the development and large investment on thin film projects and startups in 2000, and the further descent to hell of many of them 10 years later, we need to flashback to the costs of Si wafers at that time. Originally, the initial reason for the development of thin film photovoltaic (TFPV) was the need of strongly reduce the cost of materials to sustainably reduce the fabrication costs of PV modules which were very high for mainstream Si. In fact, in 2000, c-Si module prices were about 4$/Wp. From this value, just the cost of Si wafers accounted for 50%, which means 2$/Wp (Goodrich et al., 2013). At the same time the different TFPV technologies under development proposed to substitute this cost par 0.2$/Wp (cost of the deposited TF). Even if the expected performances at that time were lower than the expected efficiencies for Si technology, the calculations showing an economic advantage were clear (Powalla and Dimmler, 2000). We could hear everywhere that a 10% efficiency TF module process was the key to be cheaper than c-Si and many "low cost" projects were developed around this idea.

In 2012, with the Chinese rationalization of crystalline silicon, the reduction price of poly-silicon led to Si wafers priced at 0.25 $/Wp (http://www.PVinsights.com, 2016). At this point the evident advantage of TF at 0.2$/Wp had disappeared and no further advantages for a non-mature developing technology were apparent. If we consider 2012 GTM Research data, the total cost of materials (Si, Ag for contacts, glass, encapsulation layer, etc.) for Chinese c-Si at 16% average module was 0.43$/Wp; at the same time the total cost of materials for CIGS was around 0.35$/Wp at 13.3% while for CdTe was 0.37$/Wp at 12.6%. This means that already in 2012 there were yet a difference of about 6–8 c$ favoring TF. However, this difference was not enough to compensate the additional cost in Balance of System (BOS) associated to their lower efficiency. At this point, where fabrication costs are similar, efficiency is a key parameter determining the cost of electricity produced (measured in $/kW h). With lower efficiencies we need more modules to reach a determined nominal power, more wires, inverters, metallic structures, surface available, etc. (Fu et al., 2016; Jones-Albertus et al., 2016), which strongly influence the BOS costs in thus the final electricity price in $/kW h. Under this frame, investors seem to have integrated the small difference in materials costs (Si vs TF active layers, as glass, required contacts and encapsulation are similar

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for every glass to glass technology) limiting the market deployment of TFPV. Today TFPV continues to chase a moving target as c-Si costs, efficiency and reliability are continuously improving and investors mostly rely in c-Si product as demonstration projects are countless. This is a negative closed loop as scale factor is an important factor to reduce costs, increase efficiency in industrial environment, improve, and demonstrate reliability (which also plays a key role in the return of investment in a power system (Jones-Albertus et al., 2016). In this sense, the accelerated cost reduction learning curve for c-Si has contributed to a reduction in the market share of TF technologies from 16% in 2009 to 11% in 2012 and less than 8% at present where CdTe accounts for 5% and CIGS for about 2% of market share (Fraunhofer ISE, 2016).

Moreover, non-mature TFPV technologies face also another barrier. The development of proprietary "homemade" technologies by each different player contributes to have a cost of capital expenditures (CAPEX) higher than more mature Si based technologies, which impose a high barrier entry to new players.

In absolute numbers, the production of TF modules continue to increase due to the global market growth as it is expected for Solar Power Europe although their market share is decreased (Jones-Albertus et al., 2016). In 2009 the production of TF modules was about 1GW (for a global market of 6.4GW) while in 2017 it is expected to reach 4.2 GW for a total market of 60 GW. The global market growth opens the door to TF companies to grow and to take a part of the market to demonstrate their added value against c-Si which will allow to increase their market share. However, and considering the previous analysis, the future of TF technologies (without a real competitive advantage in material costs and thus in a face to face run with more mature Si) depends on the capacity that the different companies involved, will have to close the gap with Si technologies in terms of efficiency, costs and reliability. Innovation in product versatility and competitive advantages can contribute to create alternative or niche markets able to increase investors' confidence. One of the main advantages of TFPV, that could and should also be exploited, is the power production rate (PR) at real outdoor conditions, where TF seem to a have a real advantage (http://www.hulket.com/wp-content/uploads/securepdfs/2015/06/Eterbright_-CompetitiveAdvantages.pdf; http://www.solar-frontier.eu/en/products/product-benefits; http://www.firstsolar.com/en/Our-Advantage) thanks to its behavior at low irradiance and high temperature, and potential lightweight and flexibility of final devices. TF could have a bright future if the right decisions are taken.

The right questions to be answered, to consider a technology competitive and reliable for investors are:

– How much electricity my technology is going to produce the year around in a determined location? (productivity)
– How long will be this production under competitive conditions? (reliability)
– Which is the global cost of my produced electricity? How it compares with energy sources? (return of investment).

2. Costs overview for PV electricity

These questions are very important as they are at the origin of the expected return of investment for investors. These parameters are the underlying physical parameters to calculate for example, the weighted average cost of capital (WACC) and the rate of return (RR) which are strongly associated to risk; i.e. associated to productivity and with reliability (Powell et al., 2015). With these questions in mind, improving efficiency and reliability while reducing costs are the drivers of the present PV industry. In the case of TF manufacturers, it is also important to show innovative, social or industrial advantage against mainstream products. In this case, looking to future will also require showing advanced solutions and innovative approaches, as for example: integrated storage, integrated water splitting, customized solution (through the design of flexible enough manufacturing lines and processes), architectural alternatives, etc.

To consider all these key questions and to benchmark the technology against competitors, the real comparative value to be used is the Levelized Cost of Electricity (LCOE) (Renewable Energy Technology: cost analysis series, 2012), which should be competitive not only with other PV technologies, but also with other energy sources.

The challenge of the LCOE reduction, is that this figure of merit considers all the different parameters that enter into consideration when a PV project is engineered. In this sense, Fig. 1 shows a schema of the different aspect we need to consider each technology to estimate LCOE. The main categories are: CAPEX of the production and distribution tools as: inverters, transformers, etc.; OPEX, where the main concepts include taxes, insurances; Operations and maintenance (O&M), etc.; PROD or productivity of the installation, it means the performance rate (produced watts versus theoretical installed), including solar resources, degradation, etc.; REL or reliability of components, i.e. life time of all components of the installation (Jones-Albertus et al., 2016; Powell et al., 2015; Ran et al., 2015).

Looking to this schema, project and product developers look to reduce CAPEX, which means module prices in which refers to PV technologies and OPEX.

Something that is not directly seen in LCOE parameters but have an important impact through OPEX is the capacity the project owner has to offer an innovative solution including technical, financial, and project management innovation (as for example: innovative solutions, crowd funding alternatives, etc.), that could make the difference with other more classical proposal.

Reliability plays also a key role as it will be a determinant parameter to define the ROI of the installation.

Today module costs account for about 35% of the total project costs and thus BOS are becoming more and more important in the global cost structure (which increases even more the important key role of module efficiencies). Of course, these data will change as a function of the innovation proposed and/or the degree of customization of the product. It means that there is not a unique value for LCOE, high added value products or customized products (as for example in architectural applications) will afford higher LCOE than standard products, and thus the impact of BOS will be different in the global calculation as a "no measurable" parameter, as subjective and customer dependent appreciation, appears. This is also the case foe many niche markets.

3. How all this translates to module production

Considering all these parameters and in particular, those directly related with modules, the economic structural competitiveness of TFPV is under consolidation and will need to:

– Reach competitive module conversion efficiencies to limit BOS penalizations associated to lower efficiencies: today with Si modules with a cost below 0.5$/Wp, and projection approaching 0.35$/Wp (Current and Cost of Photovoltaics Long-term Scenarios for Market Development, 2015), BOS accounts for more than half of the price of complete system and module efficiency is more important than ever (Fu et al., 2016; Jones-Albertus et al., 2016).
– Reduce production costs: the industrialization effort accompanying R&D can't be neglected and big groups investing in proprietary CIGS need to seriously estimate the investment effort needed to strongly reduce the CAPEX. This point is especially