Comparison of Various PV Technologies

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Abstract- *Over the most recent couple of years the thin film PV innovation piece of the overall industry has consistently developed because of its lower producing cost in examination with conventional crystalline silicon advances. While thin film PV modules have demonstrated their potential in exceptional applications where c-Si modules are unsatisfactory, such as building mix, the utilization of these modules in expansive scale PV control plants requires an itemized financial investigation to survey if these innovations can be taken a toll aggressive in a period when c-Si is demonstrating an incredible potential on cost lessening.*

In this paper three advances are analyzed in an innovative and monetary perspective. The fundamental mechanical preferences and shortcomings of multi-crystalline silicon, undefined miniaturized scale crystalline silicon and cadmium telluride PV modules are broke down and an efficient examination is made for surveying the financial reasonability of every innovation for a 1 MW control plant introduced in Southern Italy. The examination is made assessing the cost of the vitality created by the three advancements in the same natural condition amid a 20 years lifetime. The model assesses the aggregate vitality yield of the distinctive advances thinking about the genuine execution in field conditions. This permits to consider the better conduct of thin film PV modules with low and diffuse radiation, together with the diverse conduct with temperature. All the principle cost drivers, for example, fabricating, establishment, activity and upkeep costs, and in addition following framework, adjust of framework and land utilize costs are utilized for evaluating which innovation best suites for a MW estimate PV control plant application and how huge is the hole between the main innovation and the developing ones.

I. INTRODUCTION

Since the first studies on amorphous silicon solar cells conducted in the mid 1970s, the main goal for the thin film PV industry has been to develop modules that could be a low-cost alternative to traditional PV modules based on crystalline silicon.

Thin film PV modules have been used for years mainly in consumer products (e.g. calculators), or in special application for which c-Si modules could be unsuitable, such as, for example, building integration.

Thin film modules have never been seen by the c-Si PV industry as a real competitor in the PV market, especially in the range of MW size applications where the lower cost of thin film modules wasn't enough to compensate a lower efficiency, nevertheless in the last few years the PV market has changed rapidly; the thin film share has grown disconnected to assembling cost such as, adjust of frame consistently, bunches of thin film makers entered the market with their items and a few thin film based multi-MW PV control plants have been introduced around the world. The reason of the thin film piece of the pie development in the most recent years can be defended by the presentation in the market of more proficient thin film PV modules that were financially savvy in a period when the polysilicon deficiency influenced the cost of c-Si modules.

After the polysilicon lack issue has been tackled, the c-Si industry contributed on growing ease high effectiveness multi-crystalline sun powered cells that could be more practical than thin movies.

For a right assessment of the genuine cost viability of various advancements in a real PV plant, module producing expense or offering cost for various innovations shouldn't be utilized as the sole term of correlation, since this can prompt off base contemplations that don't consider other cost drivers work costs.

In this paper the temperate correlation has been made on a vitality cost premise, computing the levelized cost of the vitality created by the distinctive power plants thinking about the vitality generation and all the cost drivers for building, working and keeping up the plant for a 20 years lifetime.
In the accompanying areas the primary qualities of the advancements decided for the correlation are quickly displayed.

II. MULTI-CRYSTALLINE SILICON

Between the crystalline silicon based PV innovations, multi-crystalline is considered right now the most cost focused one. Truth be told, in examination with mono crystalline silicon, it has the upside of a much lower fabricating cost, owed essentially to the crystallization procedure that is less vitality serious (e.g. it needn't bother with the Czochralski development process), and can depend on a productivity that

is relentlessly lessening its hole from the most astounding effectiveness of mono-Si sun powered cells.

Today in the market there are a few multi-crystalline modules with a productivity proclaimed by the makers at Standard Testing Conditions running from 13 to 16%, while the proficiency of mono-crystalline silicon PV modules is in the request of 14-16% and up to 19.5% for high effectiveness modules.

Consolidating the information of modules creation cost (€/m2) with the productivity data, one can without much of a stretch get the assembling expense of modules in €/Wp. This esteem can be utilized for an immediate correlation of the two c-Si innovations.

Regardless of whether it has just been called attention to previously and it will be better depicted later in the paper, it's important that the aggregate framework costs are either control related or surface related. Specifically, adjust of framework expenses and support costs are normally surface related, i.e. they increment with the expanding of the surface required for the same introduced control, and are in this way specifically identified with effectiveness. Since these expenses are a significant piece of aggregate framework costs they should be considered for a right examination between various advances. A correlation construct just with respect to assembling expenses can be considered adequately exact just if the productivity hole is sufficiently little to have the effect in surface related costs insignificant and if the conduct of the distinctive innovations in various ecological conditions is comparative.

Commercial status and market

The piece of the pie for multi-crystalline silicon innovation can be assessed in 46% of the worldwide PV showcase.

In Italy there are a few organizations delivering multi-Si sun oriented cells and modules. The Italian yearly generation limit of multi-Si sun oriented modules can not be effortlessly evaluated for the nearness of a few organizations that create modules utilizing cells imported from different nations. Just to give a thought of the generation limit of the Italian c-Si industry it can be noticed that in 2007 the 9 main makers of c-Si modules (mono-Si and multi-Si) have been represented an aggregate generation limit of 280 MWp [1].

Manufacturing cost

The most minimal module producing cost for multi-crystalline silicon can be evaluated in under 1.2 €/Wp. This cost can be besides decreased with assembling hardware institutionalization and innovation advancements that permit to utilize less dynamic material. One of the difficulties for the c-Si industry is, truth be told, the diminishment of wafer thickness without a decrease of yield, and kerf misfortune lessening amid wafer sawing, for a lessening of the particular utilization of silicon in the last module. This won't just prompt an imperative lessening of modules cost, yet additionally to a more noteworthy autonomy of module cost from polysilicon cost. A major lessening of assembling cost for c-Si modules can be come to too with intercessions all in all silicon production network. The development of new high limit polysilicon creation offices that is occurring in North America and China will prompt a major cost diminishment for silicon based cells and modules. Truth be told, an expansion of the worldwide polysilicon generation limit will be a vital driver for bringing down the crude material cost and for permitting the development of the PV business creation limit.

It's significant that a diminishment of the assembling cost for PV modules doesn't generally lead straightforwardly to a decrease of the module cost. Module costs, truth be told, are regularly determined by the market and it might happen that they can increment, regardless of whether producing costs are relentlessly diminishing, when there is an expansion of solicitations not promptly took after by an increment of module generation. This market circumstance, together with changes on monetary help laws, can likewise prompt quick changes on the comfort of a specific PV innovation in correlation with the others.

This doesn't mean, however, that the PV business doesn't need to take after a guide for assembling cost lessening. Indeed, regardless of whether this cost decrease doesn't lead straightforwardly to a diminishment on module costs, this will be fundamental in the long haul for affirming the aggressiveness of the PV business in the vitality showcase when PV created power will achieve the matrix equality, financial backings from establishments will be a bit much and there will be a more grounded relationship between's cost of vitality, module costs and module fabricating costs.

III. METHODOLOGY

Degradation in an electronic device is detected by deterioration in its output characteristics. In the case of PV modules, degradation results in a decrease in power generated by the PV module. It is, therefore essential to continuously monitor and analyze the PV parameters. Moreover, it is essential to carry out periodic current- voltage (I-V)

measurements of the PV modules to complement the data obtained from the continuous monitoring of PV modules.

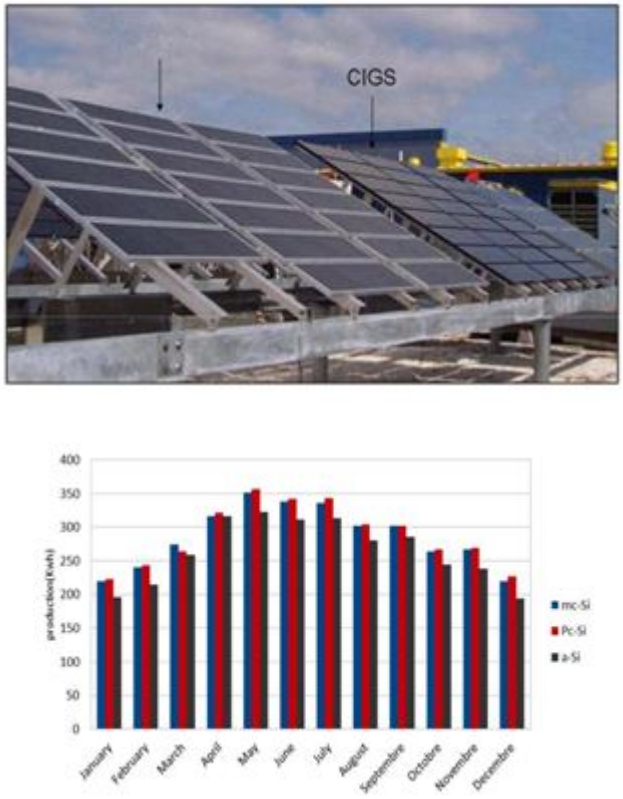

Fig:Harvested energy profile from the three-plant all year round.

can prompt enormous assembling cost diminishments. Some thin film generation gear makers express that with the presentation of new upgraded procedures and hardware, an assembling cost diminishment of 30% in the here and now can be accomplished.

Efficiency

The fundamental hindrance of thin film silicon based PV modules is low proficiency. Balanced out proficiency proclaimed by producers is in the request of 5-6%. This esteem can be expanded with the appropriation of innovation arrangements that permit to assimilate sun based vitality in a more extensive light range, for example, pair or multi-intersections and miniaturized scale crystalline/formless innovation. These arrangements enable an expansion of balanced out proficiency to values in the request of 7-9.5%.
The effectiveness esteems considered in this work are the alleged settled proficiency esteems, i.e. the proficiency of the modules after the underlying light prompted debasement owed to the Staebler-Wronski impact.

Nebulous silicon modules are described by a decent proficiency at low sunlight based radiation levels and diffuse radiation. The energy of the module is likewise less influenced from varieties of the cell temperature in correlation with c-Si modules. This attributes can in a few applications prompt a yearly particular vitality generation higher than c-Si.

Regularly a-Si modules are introduced in tilt settled help structure for their lower proficiency and cost in correlation with c-Si modules.

IV. CADMIUM TELLURIDE

The second thin film PV innovation that will be contrasted with multi-crystalline silicon is Cadmium Telluride. Despite the fact that this innovation has been created for a considerable length of time without having the capacity to increase extensive pieces of the overall industry, over the most recent couple of years it has demonstrated a tremendous development and is currently the prevailing slender film innovation with in excess of a half of the worldwide thin film module generation. The reason of this achievement can be routed to its ease in examination with c-Si and to the higher effectiveness in contrast with a-Si. CdTe modules have been utilized as a part of a few multi-MW control plants the world over and in the most recent years it has begun to be considered as a genuine contender for c-Si in expansive scale control plant applications.

Manufacturing cost

A total cost show has been made by First Sunlight based for NREL in the late 1990s [3]-[4], however not any more late information are accessible. To begin with Sunlight based in numerous gatherings and open talking announces a module fabricating cost past 1 $/Wp and other CdTe makers consider achieving this cost level conceivable because of the selection of economies of scale and affidavit forms that needn't bother with awesome material utilization and can guarantee a high return.

Efficiency

The effectiveness of CdTe modules is in the scope of 7-11% in standard testing conditions (STC). This esteem is lower than c-Si, however significantly higher than single intersection a-Si. CdTe exhibitions additionally don't demonstrate starting

Material issues

Since Cadmium is a harmful component, a few issues may emerge on its utilization in PV boards. A few investigations have been directed to assess the harmfulness capability of CdTe PV modules amid their lifetime and if there should arise an occurrence of flame. These investigations for the most part concede to the way that CdTe modules in a glass-glass epitome are not risky for the earth and neither for individuals or creatures [5].

CdTe PV modules must be discarded appropriately toward the finish of their lifetime, yet this isn't an issue since modules are willful gathered by the maker and reused. Reusing is likewise important to take care without bounds issue of accessibility of Tellurium. Indeed, even with the creating of a full reusing process with high crude material yield, the Tellurium shortage will constrain the worldwide yearly generation of CdTe modules to just a couple of GWp [6] and an expansion of Tellurium cost is accordingly unsurprising

V. COST ANALYSIS FOR A 1MW POWER PLANT

In this section the power plant attributes and the parameters utilized for the assessment of the vitality yield and vitality cost will be portrayed

Table 2 Power plant and components technical data.

	c-Si	a-Si	CdTe
Module data			
Power @ STC [Wp]	220.0	135.0	77.5
Voc @ STC [V]	36.5	60.8	90.5
Isc @ STC [A]	8.20	3.45	1.22
Efficiency @ STC [%]	13.4	9.5	10.8
Efficiency @ 200W/m^2 [%]	11.1	8.4	11.0
NOCT [°C]	47.5	44.0	45.0
P_{MPP} Temp. coeff. [%/°C]	-0.485	-0.240	-0.250
Surface [m2]	1.64	1.42	0.72
PV Plant Data			
Number of Modules	4 520	7 392	12 880
Number of Trackers	226	308	322
PV Power [kWp]	994.4	997.9	998.2
PV Surface [m^2]	7 413	10 497	9 274
Ground cover ratio	0.15	0.15	0.15
Plant surface [ha]	4.94	7.00	6.18

Energy yield for the PV power plants

For assessing the vitality yield of a PV control plant in genuine establishment conditions, a model in light of the utilization of sunlight based irradiance information has been made. Knowing the irradiance and temperature esteems with time interims of 15 minutes for each month to month reference day, the momentary PV control has been figured for each interim utilizing specialized information announced by module producers. At the point when information were not accessible a gauge of them have been finished. The introduction of the PV control between each immediate information computed inside the model permitted the following of a profile for the day by day PV control hypothetically producible by the PV plant. The incorporation of this power amid a day comes about on the every day PV vitality delivered and consequently to the month to month and yearly DC electrical vitality producers, particularly for thin movies, accordingly constructing a total and dependable cell demonstrate is relatively incomprehensible without the coordinated efforts of makers and the utilization of an improved model construct additionally in light of derating factors is in this manner required.The outcomes for the net yearly air conditioning vitality created by the three power plants, figured for the primary year are combined in Table 3.

Table 3 Net annual electric energy production.

	c-Si	a-Si	CdTe
Energy [kWh/yr]	1 820 066	1 894 763	2 010 033
Specific energy [kWh/kWp/yr]	1 830	1 899	2 014

Power plant costs

The cost of the power plants has been ascertained considering all the principle figures for building the plant and the yearly expenses for support, plant task and for save parts.

The model depends on genuine market costs for segments, where accessible, or on taught gauges at those segments whose offering cost is considered deliberately pertinent and conveyed by makers or wholesalers to outsiders or clients just under a non exposure understanding. In Table 4 a portion of the primary cost drivers that must be considered for building the PV control plant, together with their assessed cost for the three PV plants broke down in the investigation, are depicted, and in Figure 2 the effect of different segment of venture cost on add up to cost is appeared.

Table 4 Main costs for a 1MW power plant.

	c-Si	a-Si	CdTe
Modules investment cost [€]	1 909 248	1 466 942	1 557 192
Trackers investment cost [€]	1 582 000	2 156 000	2 254 000
Inverters investment cost [€]	498 735	498 735	498 735
Other costs [€]	319 199	329 734	344 794
Operation and Maintenance cost [€/yr]	41 942	45 498	47 050
Land use cost [€/yr]	24 709	34 989	30 912

Figure 2 Investment costs for 1 MW PV power plant.

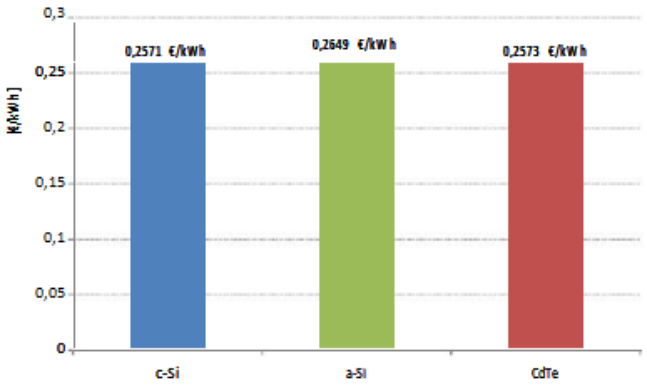

Figure 3 Levelized energy cost for the three PV power plants.

Cost of Energy

For an immediate examination of the three unique innovations under a financial perspective the levelized vitality cost has been figured.

The levelized vitality cost (LEC) is a list speaking to the unitary cost for the electrical vitality delivered by a power plant. This takes in thought every one of the expenses for building and working a power plant, and additionally extra costs, for example, fuel costs for non sustainable power source energized control plants.

The LEC, communicated in €/kWh has been computed for the three PV control plants utilizing condition 1 that permits to consider the present an incentive for the building and activity cost and for vitality creation also.

$$LEC = \frac{\sum_{N=1}^{L} \frac{I_N + O_N}{N}}{\sum_{N=1}^{L} \frac{E_N}{N}} \qquad (1)$$

where

I_n = investment cost at year n (€)

O_n = operation and maintenance cost at year n (€)

E_n = energy produced at year n (kWh)

r = discount rate

L = power plant lifetime

The value of the LEC calculated for a 20 year lifetime for the three plants analyzed in the study is shown in Figure 3.

VI. CONCLUSIONS

The PV advertise in Italy has appeared in the most recent years a major development either in matrix associated home applications and in control plants applications. The high irradiance levels and the present nourish in taxes make the interest in MW measure PV control plants extremely appealing for Italian and European financial specialists. Up to now the greater part of PV control plants have been introduced utilizing the customary c-Si PV innovation. The presentation in the market of thin film sun based modules portrayed by an effectiveness higher than 10% and an assembling cost lower than c-Si offered some conversation starters on whether these advancements could be a reasonable other option to conventional c-Si modules.

In this paper an examination between the conventional multi-crystalline silicon PV innovation and two thin film advances (small scale crystalline/formless silicon and cadmium telluride) has been made in a mechanical and monetary point of view. Specifically a monetary investigation went for assessing the cost of the vitality delivered by a 1 MW PV control plant in light of the three innovations has been finished.

The outcomes demonstrate that in the specific application considered for the investigation there is a little distinction between the cost of vitality for c-Si and CdTe based plants. Truth be told the two advancements are licensed for a cost of vitality of 0.2571 and 0.2571 €/kWh individually for c-Si and CdTe. The distinctions are small to the point that even a little change in segment costs or different expenses can prompt leeway of one innovation in examination with the other. The smaller scale crystalline/indistinct silicon innovation is authorize for a cost of vitality of 0.2649 €/kWh. The cost of vitality for a-Si is still near its rivals, however sufficiently high to make this innovation still inadmissible for MW measure framework associated on field applications.

A point for c-Si innovation is venture taken a toll. Actually, as it can be found in Table 4, fabricating a 1 MW PV control plant in view of c-Si modules requires a littler capital speculation for acquiring a comparable cost of vitality considering a 20 year plant lifetime. This is because of the higher cost for BOS parts (counting high exorbitant following frameworks) for thin movies.

The greatest shortcomings of every innovation are the place the PV business needs to work for improving its offers in the vitality showcase. Specifically, c-Si innovation must continue contributing on cost decrease for keeping up its administration even with a lower vitality yield and it must go for diminishing the vitality requirements for wafer generation for lessening its carbon impression. Miniaturized scale crystalline/nebulous silicon innovation . won't be an extraordinary contender for c-Si and CdTe unless a noteworthy advancement change for updating the efficiency or a noteworthy cost diminishment will be expert. The impact of an adequacy addition would be more noteworthy than the one related to module cost diminishment since it would incite a noteworthy lessening of BOS cost. This is the place the thin film industry needs to think the most. CdTe is right now the just thin film innovation that can be aggressive in the MW measure PV advertise. It will most likely need to confront the issue of the shortage of Tellurium and in this way a cost increment is unsurprising. Likewise for CdTe an expansion of the proficiency would be a major driver for improving its intensity while lessening complete framework cost.

Table 6 Characteristics of different PV technologies for the application in 1 MW size PV power plant.

	c-Si	a-Si	CdTe
Module Cost	7	8	8
Efficiency @ STC	9	6	7
Efficiency @ 200 W/m^2	5	8	9
Temperature coeff.	6	7	8
Energy Production	8	8	9
Material availability	7	9	6
BOS cost	9	5	6
Land Use	8	5	6

It's significant that this investigation, led for a particular area in southern Italy, isn't gone for surveying which innovation is when all is said in done the best decision, since numerous mechanical, monetary and authoritative components that influence the outcomes can change generally starting with one area then onto the next, prompting diverse outcomes.

The investigation can be stretched out effortlessly to different advancements such as, the entrenched mono-crystalline silicon innovation or CIGS and other rising advances when they achieve their market development.

REFERENCES

[1] Energy & Strategy Group, “Solar Energy Report 2008”.
[2] V. Arkhipov, J. Poortmans. Thin film solar cells fabrication, characterization and applications, Hoboken: Wiley, 2006, pp. 435-439.
[3] K. Zweibel, “Issues in thin film PV manufacturing cost reduction”, Solar Energy Materials and Solar Cells, Volume 59, Issues 1-2, 1999, pp. 1-18.
[4] K. Zweibel, “Thin film PV manufacturing: Materials costs and their optimization”, Solar Energy Materials and Solar Cells, Volume 63, Issue 4, 31 2000, pp. 375-386.
[5] V. M. Fthenakis, H. C. Kim, “CdTe photovoltaics: Life cycle environmental profile and comparisons”, Thin Solid Films, Volume 515, Issue 15, 2007, pp. 5961-5963.
[6] A. G. Aberle, “Thin-film solar cells”, Thin Solid Films, Volume 517, Issue 17, 4th International Conference on Technological Advances of Thin Films and Surface Coatings, 1 July 2009, pp. 4706-4710.