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Project 1C: Solar Cell Design and Module Manufacturing Platform

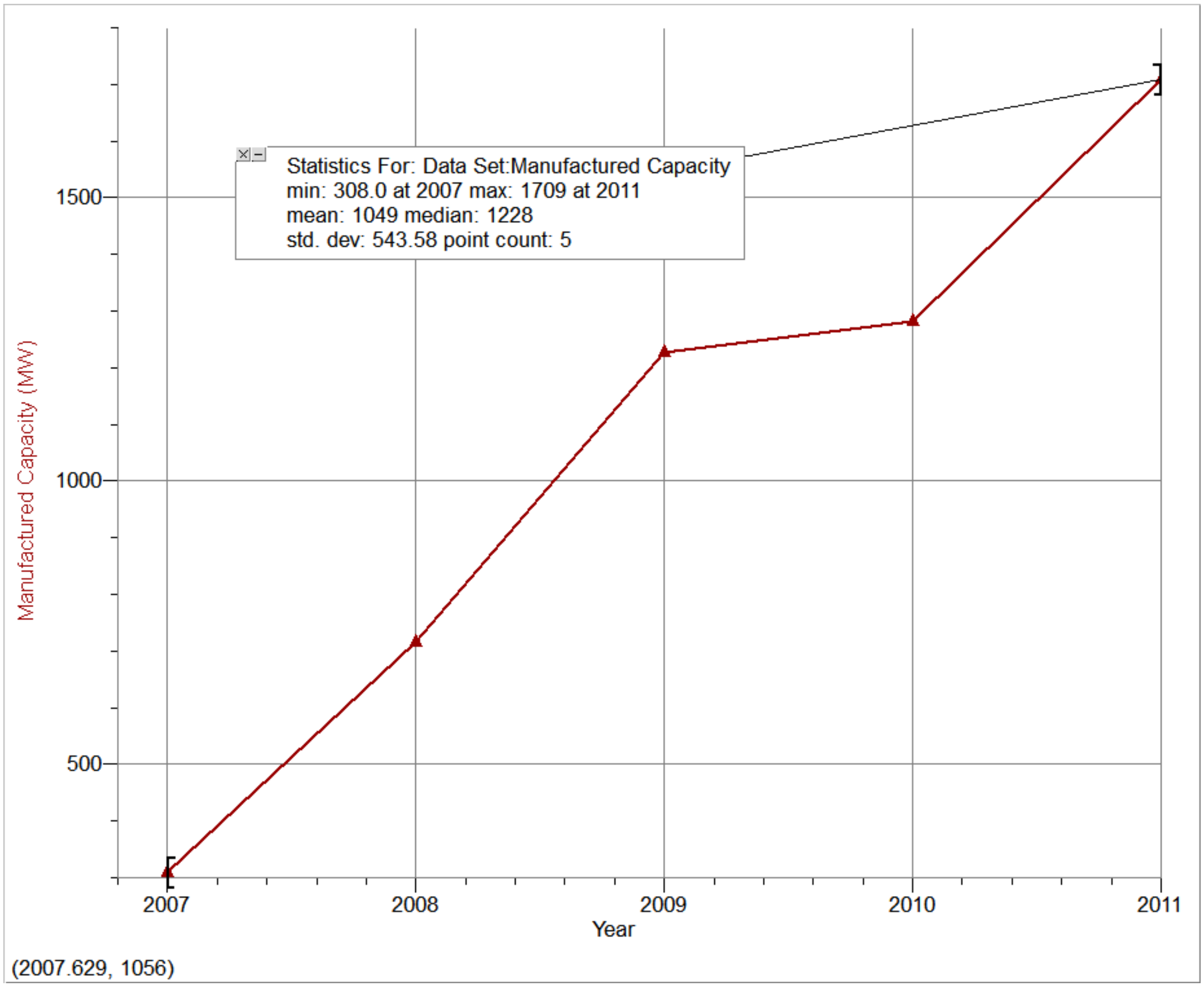
In order to fully utilize the PC1D simulator, we first had to find the correct parameters to insert for a Cadmium Telluride solar cell. Since there was no materials file for CdTe included in the program, we used the GaAs materials file and modified the band gap to 1.47 eV and the refractive index to 2.72. (Palmer, 2008) Next, we had to design an anti-reflective coating. In CdTe solar panels, there are three layers between glass substrates: CdTe, CdS, and SnO_2. The CdTe serves as the p-type semiconductor, while the CdS is the n-type semiconductor and the SnO_2 is the top electrical contact Using 2.51 and 1.459 for the indices of refraction for CdS and the top glass layer respectively, we found that the index of refraction of SnO_2 (2.006) was close to the ideal index of refraction (1.914) determined by the equation $\sqrt{n_1 n_2}$. (Refraction Index of Various Substances) In order to find the proper thickness for this AR coating, we used the equation $\frac{\lambda}{4n}$ with λ as 555 (approximately the wavelength of light with the highest intensity). This gave the thickness as 69.2 nm. However, through further experimentation with the simulator, we found that the optimum thickness was about 75 nm.

At this point though, we found the limits to the PC1D simulator in regards to modeling thin film solar panels. In CdTe solar cells, CdTe is not actually doped. CdTe is deposited as the p-type layer and CdS is subsequently sprayed on as the n-type layer. There is no option in the PC1D simulator to account for such a build. As a result of this and using the GaAs materials file, we found that our cell performed at 27.5% efficiency, well above the theoretical limit for thin-film CdTe. In order to compensate, we tried reducing carrier life, since bulk recombination would occur at a greater rate in thin-film cells. Setting the carrier life at 0.01 microseconds instead of 1 microsecond reduced efficiency to 22.3% efficiency. The PC1D simulator also fails in respect to modeling real-life situations. It does not account for indirect sunlight shining at acute angles, dust and dirt, and degradation of the cell over time.

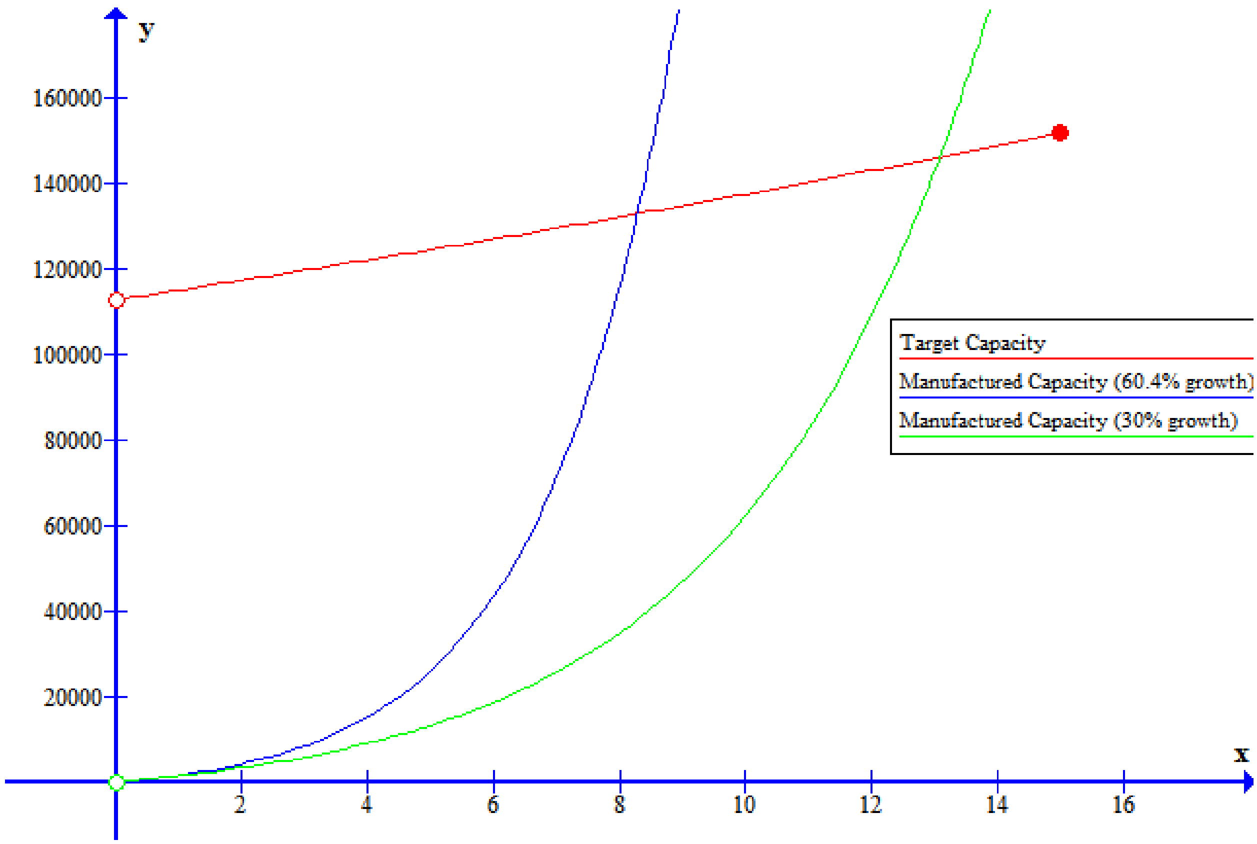
While designing the optimal cell is important in solar cell engineering, we must also take manufacturing constraints into consideration. From Project 1A, we decided that solar capacity must be able to handle 15% of the United States' summer peak load, or 112,870 MW. If the United States' energy demands continue to increase at 2%, in 100 years solar capacity must reach 817,700 MW. In a sustainability analysis, we must look at the United States' Tellurium reserves and production capacity. Taking the density of CdTe as 5.85 g/cm^3 with Te being 53% of the mass, there is about 3.1 g/cm^3 Te in CdTe. 1 micrometer over a square meter area is 1 cubic centimeter. If the average thickness of CdTe in solar cells is 3 micrometers, there are 9.3 g/m^2 Te in CdTe cells. Taking the efficiency of CdTe solar panels to be about 10% efficient, the cells produce 100 watts per square meter. Thus, producing 1 GW of solar capacity with CdTe requires 93 metric tons of Te. In 100 years, we will then need about 76,000 metric tons of Te. Since an estimated 800 metric tons of Te is available per year (ignoring the discovery of new reserves in promising areas like undersea ridges), a shortage of Te should not be a problem in the future.

Looking at manufacturing costs and technology/materials supply chains, CdTe solar cells are especially promising. Although it is necessary to account for recycling costs of toxic Cd, CdTe cell production can be fully automated since the film essentially printed on glass substrates through deposition. In addition, First Solar, the world's largest CdTe manufacturer, has adopted a vertically integrated manufacturing process to streamline production.

The question then becomes: when will solar cell production reach our target capacity? Below is a graph of First Solar's current manufacturing capacity (Fast Facts: Company Overview, 2010):



First Solar projects that it will reach 1,709 MW of solar panels produced per year by 2011. Taking the average of its growth rate over the past 5 years, its manufacturing capacity has increased by 60.4% per year. If we integrate this production over time, we will get the total accumulated capacity. Below is a graph comparing the growth of the target capacity for solar energy (2% growth) versus the manufactured capacity (at the 60.4% rate and a more conservative 30% growth rate).



If CdTe panel production continues at a 60.4% growth rate, we will reach target capacity in about 8 years. If production slows to 30% growth, we will reach target capacity in about 13 years. However, many of First Solar's cells are shipped overseas. In order to reach our goal, the government must reach out and offer incentives for U.S. consumers and utilities to purchase solar panels so we can take advantage of First Solar's production.

Works Cited

Fast Facts: Company Overview. (2010, February). Retrieved April 26, 2010, from First Solar: http://www.firstsolar.com/Downloads/pdf/FastFacts_PHX_NA.pdf

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