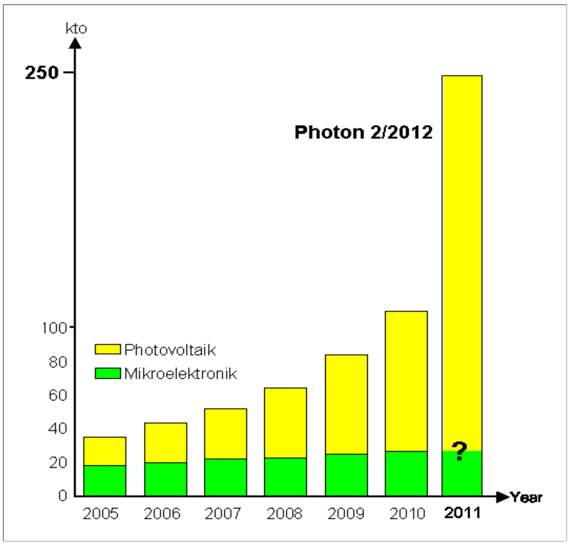
The Great Si Crisis in 2007

Advanced

- While today's buzzwords like "**energy crisis**", "**climate change**" and "greenhouse effect" have finally penetrated even the most simple minds on these planets (even George W. **Bush** knows the meaning of this words by now), more sophisticated minds knew about this already in the **70**ties of the last century.
  - That "the future" would only have a future if we would manage in time to switch from burning coal and carbohydrates to energy supplies relying on "solar" - wind, water, biofuel, solar heat and direct solar electricity via solar cells - was clear to everybody who knew a minimum about energy conservation laws and the effect of greenhouse gases. One might consider nuclear power in this context, but we won't.
  - What happened, or better what did not happen after the first and second "oil crisis" in the **70ties** (look it up in the Net), is history now. It can be safely predicted that in years to come, historians looking back on this chapter of global history will take a dim view of some present day heroes.
- Anyway, by some cunning politics and good old dumb luck, Germany started a thriving solar industry a few years after the millennium; a few other countries (foremost Japan), did the same.
  - *Predictably*, real money was made with the most old-fashioned technology: more or less "classical" solar cells made from bulk **Si** - either from (round) single crystal wafers or from so-called (square-shaped) multi-crystalline slices. Starting around **2003**, factories were built like crazy, and new companies like Q-Cells or Solarwold turned almost over night into stock market stars worth hundreds of Million **€**.
  - *Predictably*, electronic grade **Si** (even somewhat less "good" **Si** from minor suppliers) turned scarce and prices shot up. Solar cell companies without reliable sources of **Si** (i.e. without long-term contracts with major suppliers) had to give up; while others grew with growth rates only limited by how fast you could hire people and built factories (about **40 %** per year).
  - Given the growth rates of the solar industry *and* of the microelectronic industry and projecting that on the **Si** production capacities of the existing companies (just about a handful), it was pretty clear that electronic grade **Si** would become scarce around **2005**. However, given the general experience in big business, it was also clear that not much would happen *before* this predicted scarcity was really felt.
- Now, in Feb. **2007**, big articles about the **Si** crisis appear rather regularly in the relevant magazines and lots of money is diverted to electronic grade **Si** production.
  - Here are a few facts; mostly taken from the Feb. **2007** "Photon".
- Major **poly-Si** (always electronic grade now) producers like Wacker (Germany) MEMC (USA) and others are building new plants for **poly-Si** production.
  - Besides just cranking up the established production with the **"Siemens" process** as described in the backbone; new variants of the basic **CVD** process are being tried and moved to production. Extremely simplified, instead of having a thin **Si** rod grow by depositing **Si** in a relatively small reactor, "**Si** dust" is fed into the top of a huge heated tower, where it slowly sinks down in a strong upward draft provided by silane and hydrogen gas (plus the doping gases) fed into the tower at the bottom.
  - The dust particles grow while sinking; if all goes well, you can eventually shovel out some **Si** ***gravel*** at the bottom.
  - Sound simple, is not. Just the PH_3 or B_3H_6 inside a decent sized reaction tower would be sufficient to wipe out a big city if it ever gets out.....
  - As a very raw but interesting number in this context we note that a production capacity of **10.000 to/a** will cost you $(0.5 - 1) \cdot 10^9$ **€** initial investment; you also need the (very secret and closely guarded) know-how.
- Here is a prediction of how much **Si** we will need in years to come. The average growth rate is about **25 % /a**; accelerating as time goes by.



Data from "Photon" **2**, 2007

Here is some of the present (Nov. **2007**) gossip around the **Si** crisis:

- "Orkla ASA" (Norwegian company) builds a **323 Mio €** plant for producing solar **Si** by direct cleaning of metallurgical **Si**. Capacity is **5.000 to/a** in **2009**. "ELKEM", a Orkla daughter company, is the world's largest producer of metallurgical **Si**.
- "Dow Corning" (USA company; not much previous **Si** experience) announces end of **2006** (as a surprise) that it will produce **1.000 to/a** of solar-grad **Si** by some process for cleaning metallurgical **Si** (in Brazil).
- **4** other companies are making similar, but less specific announcements.
- About **20** more companies (including Chinese) are suspected to secretly work on some **Si** production process based on cleaning metallurgical grade **Si**.
- **1 kg** of solar **Si** presently costs about **50 €** (if you have a good contract with a supplier), on the "spot market" you may have to shell out **150 €/kg**. Prices have gone up **30 %** and more during the last **3** years.
- Some numbers from the **May 2008** "Photon": Average price now about **70 $ /kg**; Spot market price up to **515 $/kg**; production costs about **36 $/kg**. Looks like the crisis is still with us. About **70** companies now make solar **Si**, about **100** more have announced to get into this market.
- The projected **110 kto/a** in **2010** is still not enough for the expected market for solar cells. This may mean, that the thin film solar cells, which so far are just a niche production, may come into there own.

Obviously, the new game in town is to take cheap metallurgical grade **Si** (at around **1 €/kg**) and to clean it "directly", avoiding the costly (**CVD**) Siemens process. It's actually not all that new; I have worked along those general lines around **1991** in the Siemens labs in Munich myself.

So how is it done? Few people know - whatever is going on is ultra secret, and all the players in this field have their own little "dirty" or better "cleaning" tricks. Before we look at some of those tricks, we will look at the money side of things a bit more.

The only definition of what defines "**solar grade" Si** as a subgroup of "electronic grade **Si**" is how good the solar cell will be that is manufactured with the stuff; in other words what kind of cell efficiency η (electric power out/ Light power in (in **%**)) you can get with your process.

A few rough numbers to that are: If the best efficiency you can get is below η **= 13%** - forget it. Even if your **Si** would be for free, it's too expensive. On the other hand, if you can get an η **= 15%**, you can ask for about **40 €/ kg**. This just shows how dramatically important the cell efficiency is (and how difficult to increase it relative to the best you can do).

In other words: If you make or loose huge amounts of money by going into the **Si** business depends on many variables most of which you don't know all that well.

Last, let's look at some ideas of how to clean metallurgical grade **Si** cheaply and efficiently. First, we have to realize that what works for some impurity many not work for some others, so we have to group impurities in e.g. metals, doping elements, **O** and **C**, and so on. A few typical processes might be

- Melt the stuff and throw some slag-formers in the melt (e.g. **$CaSiO_2$**) Doping elements like **B** and **P** might prefer to be in the slag, which you then spoon off with a ladle (haha).
- Melt the stuff and blow gases through the melt. With some luck (or special knowledge) - see above).
- Solidify your melt in a suitable way ("directional solidification") and use "segregation" to move a lot of the (metallic) impurities into that part of the melt that solidifies last (which you throw out then).
- Bath your (finely crushed) **Si** in suitable acids and lyes and dissolve the dirt sitting on the surface. If you crush material full of defects (particularly grain boundaries) after some treatment that drove your impurities into the defect sites, and if you crush it in such a way that fracture occurs at grain boundaries, you may now chemically remove a lot of the dirt.
- Keep our energy needs down. Melting a **kg** of **Si** takes a certain amount of **kWhr**; so does heating your equipment. The Siemens process runs up a bill of about **100 kWhr / kg**; cleaning metallurgical grade **Si**

may keep it a **15 kWhr/kg**.

- Don't just take any metallurgical grade **Si** - make your own with "optimized" dirt in there. Find a source of relatively clean coal and quartz - at least with respect to the more trickier impurities.

Let's stop here. If you get my drift, you will now understand that there are many interesting and demanding jobs out there for engineers who know their electronic materials, and that the **Si** crisis can and will be solved very quickly. Exactly how remains to be seen.

- As an afterthought: The situation has many parallels to the introduction of steel mass production of the second half of the **19**th century. People were fighting impurities, had no clear idea of exactly what was needed, and found a lot of working solutions that were only understood later.