Unraveling the Puzzle that is Solar PV Pollution

——Clean Production of Solar PV Manufacture in China

As its name implies, clean energy, including the use of and conversion of solar power, should be *clean*. This is a fair demand put to the solar PV industry. Unfortunately clean production has yet to come to fruition. Greenpeace has reviewed multiple stages of production throughout the solar PV industry chain, and found that the hurdles that lie between China and clean production don't lie in technology, but instead with will. The Solar PV industry can and should upgrade itself according to the current environmental discharge standards, as well as implement environmental protection standards to realize clean production. By reducing or even eliminating pollution, solar power can indeed become clean.

This report is the first of its kind, reviewing the current status of clean production in China's solar PV industry. The report takes a close look at the environmental impacts of different phases of solar PV production, calculates the energy payback time of solar PV products, and explores the economic dynamics of solar PV clean production. In responding to the concerns revolving around the status of China's solar PV clean production, we seek to present a realistic depiction of the solar PV industry for investors, decision-makers and the general public. Practical improvement measures are also offered in this report.

Executive Summary of the Report:

• Is solar PV industry clean currently?

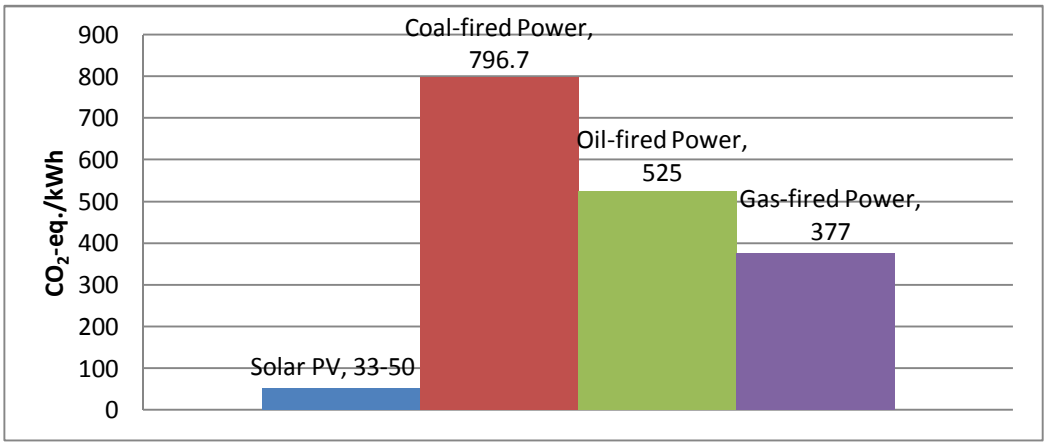
The solar PV manufacturing industry is on its way to becoming clean, but still has some steps to go. Take upstream polysilicon production as an example, there are around 70 producers in China, of which only 20 had pass the 'National Polysilicon Industry Entry Requirements', which was published by Ministry of Industry and Information Technology in 2010 and is to regulate and guide the polysilicon industry in terms of environmental impacts, energy consumption and sustainable development. It is noted that less than one third of polysilicon producers can meet the environmental and energy standards of clean production. These 20 enterprises vary in size, with some reaching the capacity of 10,000 tons, while others with much smaller capacity. Some are under construction or not in production, with the number of enterprises who can continue their production being at less than 10.

Besides polysilicon producers, there are 700-800 downstream module and system manufacturers. Among them, only a few publicly-listed companies have released CSR

reports which disclose their figures for energy consumption and the “three wastes” (waste gas, waste water and waste residues). These reports appear to be the only channel in which to disclose environmental information of solar PV enterprises. This indicates a lack of understanding in regards to clean production from Chinese enterprises, with pollution control efforts being superficial at best. Consequently violations frequently occur, with enterprises taking advantage of various loopholes in the pollution control system.

Is solar PV power truly low-carbon?

Generally speaking, the life cycle of a solar PV system is 25 years while its energy payback time is only 1.3 years. That means in the subsequent 24 years solar PV system has zero carbon emissions. The GHG emissions of Crystalline-Si PV power generation is 33~50g CO2-eq./kWh, compared with coal-fired power's 796.7g CO2-eq./KWh, oil-fired power's 525g CO2-eq./kWh and gas-fired power's 377g CO2-eq./KWh. Carbon footprint from solar PV power generation are only one tenth to one twentieth of those from fossil fuel power generation. So yes, Solar PV can indeed be considered low-carbon energy.



Which stage can be the biggest polluter? And which stage has the greatest potential for improvement?

The following table evaluates the environmental impact of major solar PV manufacturing phases. It’s worth noting that the stage involving polysilicon production produces the most pollution and is also the most energy intensive. There is large potential for pollution control and energy reduction during this stage. Doing so may also prove to be of

economic benefit to polysilicon producers. The industry should innovate and view the improvement of clean production technology as part of their core strategy in business.

Phases of Production	Three Wastes	Energy Consumption	Potential of Discharge Reduction	Potential of Cost Reduction	Evaluation
Polysilicon	◕	●	●	◕	• High levels of discharge • High energy consumption • Excellent potential for discharge reduction • Excellent potential for cost reduction
Silicon ingot	◑	◑	◕	◑	• Mid-levels of discharge • Medium energy consumption • Excellent potential for discharge reduction • Some potential for cost reduction
Silicon wafer	◕	◑	◕	◕	• High levels of discharge • Medium energy consumption • Excellent potential for discharge reduction • Excellent potential for cost reduction
Cells	◑	◕	◑	◔	• Mid-levels of discharge • High energy consumption • Some potential for discharge reduction • Minor potential for cost reduction
Modules	◔	◔	◔	◔	• Low-levels of discharge • Low energy consumption • Minor potential for discharge reduction • Minor potential for cost reduction
System	◔	◑	◔	◔	• Low-levels of discharge • Medium energy consumption • Minor potential for discharge reduction • Minor potential for cost reduction

Can we solve the problem of pollution in production? And how?

Solar PV manufacturing has been in development for a significant period now, and has reached a stage where we should expect it to operate cleanly. Technological solutions exist to the discharges that occur in PV production. For instance, in polysilicon production, discharge of $SiCl_4$, a hazardous chemical, has been a huge cause of concern. The use of cold hydrogenation technology can increase conversion rates of $SiCl_4$, while the use of closed loop technology can effectively solve the problem of $SiCl_4$ and $SiHCl_3$ discharge, so that they can be recycled and reused. With regards to hydrofluoric acid pollution in the Jinko incident, we can nullify fluorinion with alkali neutralization and then process the solid waste accordingly. Meanwhile waste from hazardous chemical production should be sent to certified departments or authorities for disposal in strict compliance with operational procedures. These measures and technologies have already been adopted by some domestic enterprises, indicating the question of technology is not holding the industry back from clean production.

Which phase has the highest energy consumption in the solar PV manufacturing chain?

Our investigation indicates that in the production chain it's the manufacturing of polysilicon that has the highest energy consumption.

According to the average energy consumption rate of a domestic solar PV manufacturer, we provide the following calculations. According to an industry consumption average (eight tons of silicon material produces 1MW of silicon chips), the energy consumption of the industry chain from polysilicon to solar PV system is **1.032~1.658kWh per Wp**. (We have excluded the energy consumption of silica sand and metallurgical-grade silicon.)

	Polysilicon	Silicon ingot	Silicon wafer	Cells	Components	System
Per unit consumption	80-150 kWh/kg	7-9 kWh/kg	2 kWh/kg	0.15 -0.2 kWh/Wp	0.02 kWh/Wp	0.15 kWh/Wp
Proportion of energy consumption	56%-72%	4-5%	2-3%	12-14%	1-2%	9-20%

Why aren't enterprises currently meeting the standards of "three waste" discharge?

1. Regulation from local governments is not effective and their enforcement of laws isn't strict.
2. The cost of incompliance with discharge standards is too low. This means enterprises don't have any incentive to meet standards in terms of conventional pollution (waste liquid, waste gas and solid waste), BOD (biochemical oxygen demand) and COD (chemical oxygen demand).
3. Insufficient training for staff that need to specialize in hazardous chemical management. Lax management can also give rise to incidents of environmental pollution.

What are the key clean production technologies?

The following are key clean production technologies identified by this investigation as both green and cost-effective:

1. Cold hydrogenation technology used in polysilicon production.
2. Closed loop technology used in polysilicon production.
3. PEG (polyethylene glycol, cutting fluid) recycling technology used in silicon chip cutting.
4. Replacement of steel wire saw with diamond wire saw used in silicon wafer cutting.

How would an upgrade of clean production technology affect cost to enterprises?

In the solar PV industry, use of clean production technologies not only helps enterprises fulfill various national environmental protection standards, but also helps them reduce costs in the long run. This improves their competiveness, which is of both environmental and economic value.

Upstream polysilicon production accounts for the largest proportion in total electricity cost, approximating at 36%. Use of cold hydrogenation technology and closed loop technology can reduce electricity cost to a large degree. But because of the high costs involved in initial investment, only 60% of enterprises in China use these technologies, lagging far behind the international level of 90%.

In downstream silicon wafer production, wire saws and slurry accounts for 33% of the

total cost. Use of diamond wire will improve efficiency and reduce cost. Reusing cutting fluid will also reduce the cost of processing silicon chips. Our on-site interviews with enterprises indicates that in chip production if the ratio of new cutting fluid to old one is raised from 7:3 to 6:4, production cost of 1MW silicon chips can be reduced by 300,000RMB.

- **What are the major barriers to achieving clean production?**

1. Most domestic enterprises are still centered on waste and pollution control at the end of pipe as opposed to tackling the problem from the very beginning and upgrading their production technologies. This increases pollution control costs and leads to unsatisfactory results.
2. There is lack of industry regulation and consistent production standards: local governments rush to launch various solar PV manufacture programs in order to develop new energy industries; to attract investment, relevant government departments and industrial parks sometimes lower “three waste” discharge requirements and ineffectively enforce environmental standards; and supporting pollution treatment facilities are inadequate. These factors contribute to the environmental hazards of the solar PV industry.
3. Demand exceeds supply in the early stage of the development of polysilicon industry and thus enterprises ignore environmental standards in order to make more benefit. In comparison to the rest of the globe, the Chinese solar PV industry started relatively late, which means capacity and facilities are still underdeveloped.

- **How can the current situation of clean production be improved?**

1. Environmental protection authorities need to strictly implement environmental protection standards and enhance regulation.
2. Authorities also need to regularly upgrade industry standards of clean production and establish relevant certification system. Governments or industry associations and enterprises also need to release annual clean production reports.
3. The enterprises should start the clean production from the source and efforts should be made to realize clean production throughout the industry chain.
4. Technologies should be enhanced to achieve sustainable development of clean production.