# Is Solar Power More Dangerous Than Nuclear?

by Herbert Inhaber

Consider a massive nuclear power plant, closely guarded and surrounded by barbed wire. Compare this with an innocuous solar panel perched on a roof, cheerfully and silently gathering sunlight. Is there any question in your mind which of the two energy systems is more dangerous to human health and safety? If the answer were a resounding "No", the matter could end there, and the editors would be left with a rather unsightly blank space in their journal. But research has shown that the answer should be a less dramatic but perhaps more accurate "maybe".

How can this be? Consider another example. In the driveway we have two vehicles. One is a massive lorry, and the other a tiny Mini. Which of the two is more efficient? No, not larger – more efficient. Their relative size is easy to judge, but efficiency involves the amount of petrol used, the distance travelled, as well as the weight carried.

The moral? You can't judge the relative risk of an energy system merely by its size or fearsome appearance. You must find the risk per unit energy – that is, its total risk to human health divided by the net energy it produces. This is the only fair way of comparing energy systems.

In addition, we must consider the *total* energy cycle, not one isolated component. If you calculate the risk of only part of a system and compare it with the corresponding part of another, by judiciously choosing the component you could prove that any energy system is riskier (or safer) than any other system. You would obviously be proving precisely nothing.

You may wonder why the Atomic Energy Control Board (AECB), the main regulatory agency for nuclear power in Canada, is concerned with this question. We do our best to minimize nuclear risk, but we are not in the business of regulating other energy forms. The answer is simple: the AECB has been studying the risk of nuclear power, but the results will have more meaning if they are put into context. That is, finding that nuclear power produces a certain number of man-days lost per megawatt-year has only a limited meaning to non-specialists. Knowing that this value is twice (or half) that of other energy systems means a lot more.

We can calculate the net energy output easily enough. But what is the total risk? The new field of risk accounting addresses this question.

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By now, most people working on energy questions have heard of energy accounting This extension of the accountant's art adds up all the energy required for components of a system in order to determine the overall energy requirement. For example, a coal-burning electricity plant needs X kilowatt-hours of energy to mine each tonne of coal, Y to lay each kilometre of track to transport it, Z to construct each turbine, and so on By summing the required energy inputs, we can compare the result to the output

Risk accounting is based on the same principles. All sources of risk are evaluated in terms of the deaths, injuries or diseases they cause. This implies that we evaluate not only the final stage of energy production, but the initial and intermediate stages. For example, in the two cases mentioned in the first paragraph, we would evaluate the risk in mining the sand, copper, iron, coal, uranium and other raw materials that are required, as well as the risk due to fabricating them into glass, copper tubing, fuel rods, steel and all other necessary components. To this would be added the risk associated with transporting material, manufacturing components, and the more obvious risk of constructing and operating the nuclear-powered station or solar panel

Risk accounting has been around a long time, in various guises. For example, nuclear power, coal, oil and natural gas were compared in terms of risk per unit energy by C.L Comar and L A. Sagan in a landmark article in the 1976 *Annual Review of Energy.* They found that, when all the major sources of risk for each technology were summed nuclear power had a substantially lower risk than coal- or oil-burning stations. Other studies both before and after have confirmed this.

But those who are uneasy about nuclear power, or who even denounce it, rarely advocate a return to coal and the smoky cities we all faced a few decades ago Rather, they usually propose the use of "alternative", "soft" or "non-conventional" technologies such as solar, wind, ocean thermal, methanol, geothermal and a panoply of others. The question then is, what is the risk of each of these technologies compared with conventional systems like coal, oil and nuclear?

Results of our risk accounting are surprising, to say the least. They indicate that when all the sources of risk are accounted for, most non-conventional technologies fare rather badly in comparison with conventional ones. Figure 1 shows our results. The vertical axis refers to the total man-days lost by both workers and members of the public due to deaths, injuries or disease per unit net energy output for each system. To combine fatalities with less serious disabilities, an arbitrary number of man-days lost (6000) was assigned to each death.

Electricity produced from natural gas has the lowest risk of the 11 technologies (five conventional, six non-conventional) It is a factor of about two lower than the next highest, nuclear power Third is a non-conventional system, ocean thermal, which can convert the temperature differences of ocean layers into electricity. Most other non-conventional systems have far higher risk. However, the highest of all are coal and oil, with risk about 400 times that of natural gas.

**Materials add risks**

What are the reasons for these surprising rankings? The details are contained in a recent report* The main reason why non-conventional systems have relatively high risk is the large

* *Risk of Energy Production* 1978, No AECB-1119 Atomic Energy Control Board, PO Box 1046, Ottawa, Canada, K1P 5S9.

amount of materials and labour they require per unit energy output. Why should solar need more materials than coal or oil? It's because of the diffuse nature of the incoming energy solar and wind energy are weak, and require large collection and storage systems to amass an appreciable quantity of energy Coal, oil and nuclear systems deal with concentrated forms of energy and so require less apparatus This argument is simplistic and glosses over many lesser considerations, but is generally found to be true. Figure 2 shows the results of these calculations.

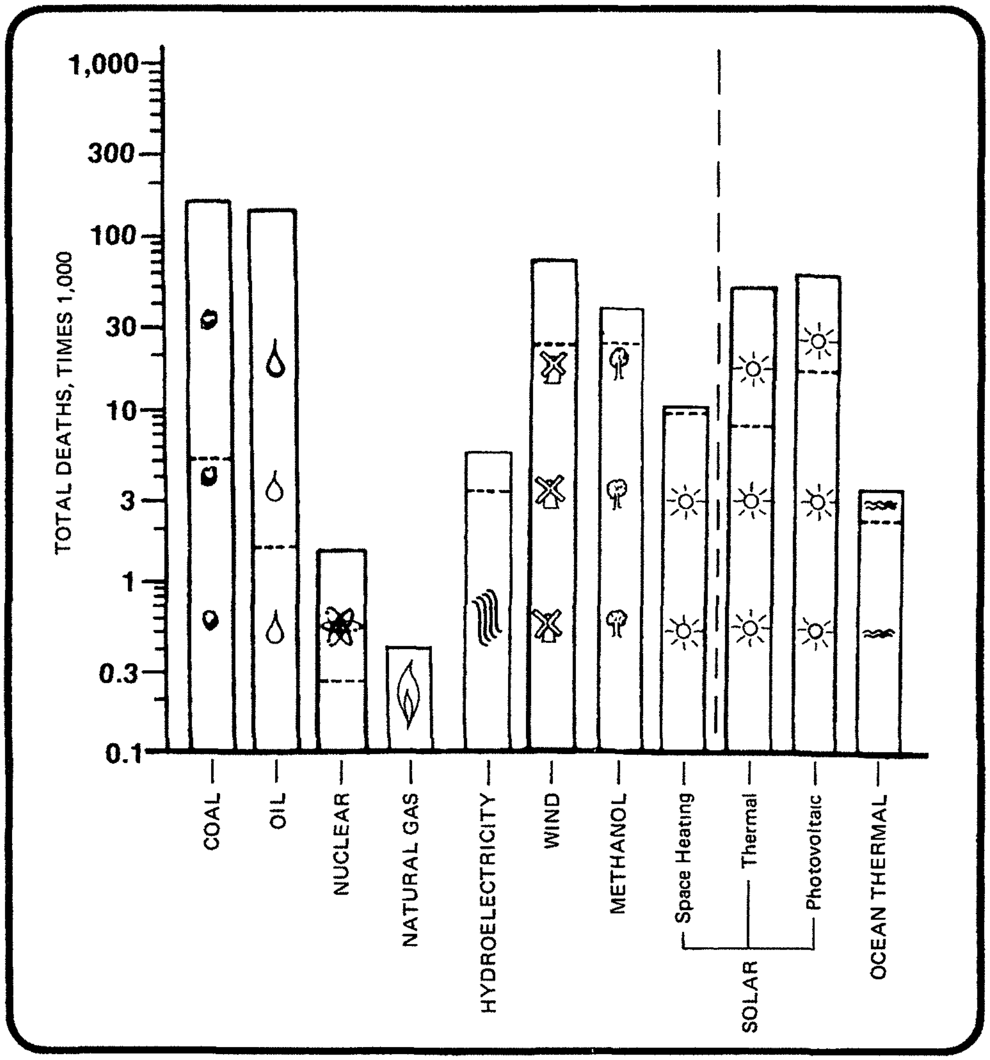



**Figure 1.** Total risk per unit energy output (one megawatt-year) for 11 energy systems. Each system has a range of values The maxima are the tops of the bars, the minima are the horizontal dotted lines. Natural gas has a very small range. Bars to the right of the vertical dotted line indicate those systems which are not likely to be used in Canada in the near future. Note the logarithmic scale.

The large quantity of materials required for unconventional systems implies huge industrial efforts in mining, refining, fabricating, and constructing the collectors, storage systems and all related apparatus. Every form of industrial activity has an associated risk, which can be

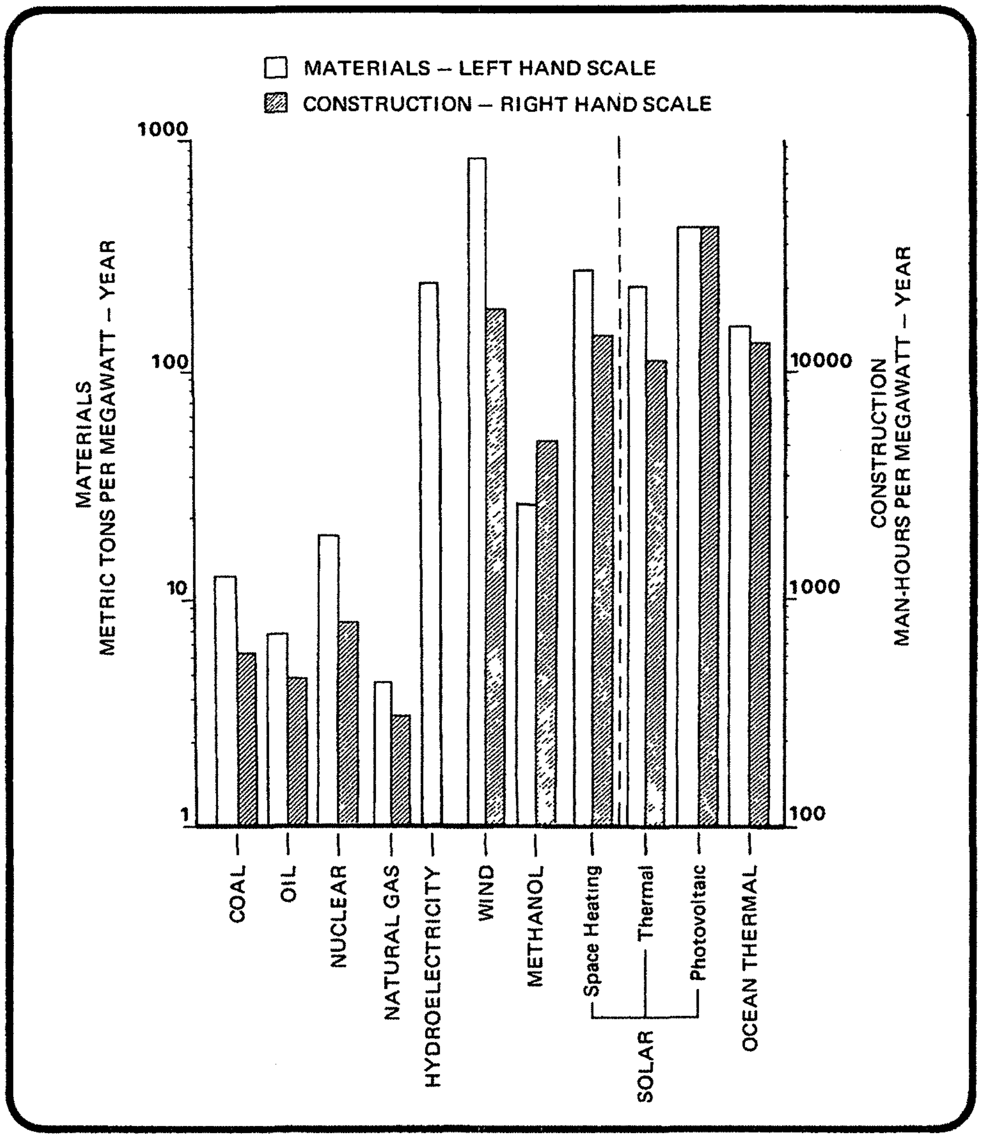



**Figure 2.** Material and construction time requirements are greater for non-conventional as compared with conventional systems (the first five on the left). Natural gas has the lowest requirements of both types. Windpower has the highest material requirements, and solar photovoltaic the highest construction times. The ratio between the highest and lowest values in each category is between 100 and 200. Energy systems to the right of the dotted lines probably will not be used in Canada for the foreseeable future because of the country's climate.

found through accident statistics compiled by national organizations. When all the multiplications and additions are done, we find that the risk from unconventional energy systems can be substantial.

This raises an interesting point. Although these systems are labelled unconventional, their risk comes, in the main, from highly conventional sources. In other words, the risk from windmills doesn't come primarily from a blade flying off and hitting you on the head, and the risk from solar space heating doesn't arise from falling off the roof as you make that last little adjustment. Rather, it comes from the more mundane tasks of mining the coal iron and other raw materials and fabricating them into steel, copper and glass.

The overall risk, as shown in Figure 1, may be divided into two categories: occupational and public risk. Occupational risk is incurred by those connected to the process of producing and operating an energy system: public risk is incurred by everyone else Because of the different mixes of materials and labour in each energy system the rankings within each of the two risk categories are not necessarily the same as for the overall risk. Results for each of the two categories are given in Table 1.

In terms of occupational risk, natural gas used to produce electricity ranks lowest, followed closely by nuclear. This occupational risk includes, for example, that incurred in drilling, building pipelines, constructing distribution networks, and so on. Coal risk is much higher. While the risk per hour spent in the mine is not strongly dissimilar for coal and uranium miners, the latter worker produces far more energy per unit time worked. As a result, his occupational risk per unit energy is much lower.

The remarkably high occupational risk for methanol is primarily due to one factor — logging. In Canada ( and elsewhere in the world), this is a job with quite high accident rates. Plans for methanol plants have implied that large volumes of wood would be gathered, so the risk would be commensurately large.

However, in terms of public risk methanol ranks second lowest, behind natural gas used to make electricity. As far as is known, the combustion of methanol produces little or no air pollution, so the risk to the public is close to zero. On the other hand, most of the large public risk from coal and oil combustion is derived from air pollution.

How can unconventional technologies like wind or solar thermal (the "power tower" concept) have substantial public risk? The answer is simple. The production of the metals needed in many unconventional technologies requires that coal is burned, and this coal will produce air pollution, which in turn causes public health effects. In addition, public risk is produced by the necessary back-up system, required for when the sun doesn't shine and the wind doesn't blow.

It may well be contended that the first of these two sources takes the analysis too far back, that the coal, iron ore and other raw materials are too removed from the final production of energy to play a part in risk accounting However, the role of basic materials in the analysis is important. If energy is needed, the nuclear plants or solar panels must be built. To produce the plants or panels, we need to mine, refine, fabricate, and install the raw and intermediate materials, the components and finished products We cannot avoid risk by ignoring it just because it happens to somebody else.

The energy system with by far the greatest amount of controversy about its risk is undoubtedly nuclear power. In a study of this type, we could not review all the claims and

**Table 1. Risk in man-days lost per unit energy output**

| | Occupational | Public |
|---|---|---|
| Coal | 73 | 2010 |
| Oil | 18 | 1920 |
| Nuclear | 8.7 | 1.4 |
| Natural Gas | 5 9 | – |
| Ocean Thermal | 30 | 1.4 |
| Wind | 282 | 539 |
| Solar: | | |
| Space Heating | 103 | 9.5 |
| Thermal Electric | 101 | 510 |
| Photovoltaic | 188 | 511 |
| Methanol | 1270 | 0.4 |

counter-claims about nuclear risk which have been made, especially with respect to reports such as the 4000-odd pages of the Rasmussen study on nuclear reactor safety (WASH-1400). Instead, a survey was taken of the major papers in the scientific literature which had estimated aspects of nuclear risk, including a monograph written by a well-known nuclear critic, John Holdren of the University of California at Berkeley For each component of risk, the highest value from the group of scientific sources was used This procedure, not followed for any other energy system, was chosen as a way of removing suspicion of pro-nuclear bias which often clouds energy debate

**Accounting for hazards**

There isn't room here for a full discussion of the methodology – the full AECB report contains further details of its features. However, because material acquisition and construction produce large risk for some energy systems, a brief review may be useful Suppose mining X tonnes of coal or any other material to produce a unit output of net energy requires Y man-years If the number of man-days lost per year of work is Z, then the number of man-days lost per unit of energy output is YZ/X. A similar calculation is made for the number of man-hours per unit energy output and the risk associated with various required occupational categories such as engineering, construction, operation and maintenance, and so on We find the risk associated with each part of the system in the same way, and add them to determine the total The calculations require no advanced mathematics or abstruse models, merely the ability to multiply and add.

This type of calculation implies that certain data are available. the time required per unit of production, rates of industrial accidents, disease and death, construction times, and, raw material requirements for industrial processes While none of these data is known absolutely, they are known adequately for purposes of a general study such as this Because the same methodology was applied to all the systems, wherever possible, potential inadvertent bias was reduced to a low level Different methodologies were used for such risk sources as transportation, air pollution and waste disposal Every effort was made to ensure that all energy systems considered were treated as uniformly as possible.

Contrary to the intuition of many people, the risk to human health (and its resulting consequences) per unit energy from unconventional energy sources such as solar and wind are apparently higher than those of conventional sources such as electricity produced from natural gas and nuclear power. There are at least two reasons why intuition fails: first, we tend to ignore all parts of the energy cycle except the last, most visible aspect, and secondly, we forget that risk must be compared in terms of unit energy output.

The above conclusions have implications beyond that of energy Many people have advocated the use of decentralized energy systems as part of a political and economic process Due to the risk they entail, material requirements alone may preclude this option. Neither I nor the Atomic Energy Control Board propose the use or non-use of any particular energy system. However, all of us must have knowledge of the risks involved in order to make reasoned judgements on the technical acceptability of a particular system

# TOXIC CHEMICALS IN SOLAR PANELS AND THEIR EFFECTS

**Solar panels may be an appealing choice for clean energy, but they harbor their share of toxic chemicals.**

The toxic chemicals are a problem at the beginning of a solar panel's life -- during its construction -- and at the end of its life when it is disposed of. These two intervals are times when the toxic chemicals can enter into the environment.

**The toxic chemicals in solar panels include cadmium telluride, copper indium selenide, cadmium gallium (di)selenide, copper indium gallium (di)selenide, hexafluoroethane, lead, and polyvinyl fluoride. Additionally, silicon tetrachloride, a byproduct of producing crystalline silicon, is highly toxic.**

## Cadmium Telluride

**Cadmium telluride (CT) is a highly toxic chemical that is part of solar panels. In the journal, "Progress in Photovoltaics," it reported that male and female rats that received CT through ingestion did not gain weight as they normally should have. This lack of weight gain occurred at low, moderate and high doses. When inhaled, CT also prevented normal weight gain and caused lung inflammation and lung fibrosis, a hardening of lung tissue. From low to high doses of inhaled CT, the weight of the lungs increased. Moderate to high doses of inhaled CT proved lethal.**

## Copper Indium Selenide

**The study of rats in "Progress in Photovoltaics" showed that ingestion of moderate to high doses of copper indium selenide (CIS) prevented weight gain in females but not males. Moderate to high doses of inhaled CIS increased the weight of a rat's lungs and increased lung fibrosis. Lungs exposed to CIS produced high amounts of fluid. Another study of CIS on rats, reported in "Toxicology and Applied Pharmacology," revealed that inhaling CIS caused rats to develop abnormal growths in their lungs.**

## Cadmium Indium Gallium (Di)selenide

**Cadmium indium gallium (di)selenide (CIGS) is another chemical in solar panels that is toxic to lungs. The "Journal of Occupational Health" reported a study in which rats received doses of CIGS injected into the airway. Rats received CIGS three times a week for one week, and then researchers examined lung tissue until three weeks after that. The scientists used a low, moderate and high dose of CIGS. All doses resulted in lungs that had spots that were inflamed, meaning they were damaged. Lungs also had spots that produced excessive fluid. These spots worsened as time went on after the one week of exposure.**

## Silicon Tetrachloride

**One of the toxic chemicals involved with solar panels is not what's in the panels but is a byproduct of their production. Crystalline silicon is a key component of many solar panels. The production of crystalline silicon involves a byproduct called silicon tetrachloride. Silicon tetrachloride is highly toxic, killing plants and animals. Such environmental pollutants, which harm people, are a major problem for people in China and other countries. Those countries mass-produce "clean energy" solar panels but do not regulate how toxic waste is dumped into the environment. The country's inhabitants often pay the price.**

# The Trouble With Solar Waste

The International Renewable Energy Agency (IRENA) in 2016 estimated there was about 250,000 metric tons of solar panel waste in the world at the end of that year. IRENA projected that this amount could reach 78 *million* metric tons by 2050.

**Solar panels often contain lead, cadmium, and other toxic chemicals that cannot be removed without breaking apart the entire panel. "Approximately 90% of most PV modules are made up of glass," notes San Jose State environmental studies professor Dustin Mulvaney. "However, this glass often cannot be recycled as float glass due to impurities. Common problematic impurities in glass include plastics, lead, cadmium and antimony."**

**Researchers with the Electric Power Research Institute (EPRI) undertook a study for U.S. solar-owning utilities to plan for end-of-life and concluded that solar panel "disposal in "regular landfills [is] not recommended in case modules break and toxic materials leach into the soil" and so "disposal is potentially a major issue."**

**California is in the process of determining how to divert solar panels from landfills, which is where they currently go, at the end of their life.**

California's Department of Toxic Substances Control (DTSC), which is implementing the new regulations, held a meeting last August with solar and waste industry representatives to discuss how to deal with the issue of solar waste. At the meeting, the representatives from industry and DTSC all acknowledged how difficult it would be to test to determine whether a solar panel being removed would be classified as hazardous waste or not.

The DTSC described building a database where solar panels and their toxicity could be tracked by their model numbers, but it's not clear DTSC will do this.

"The theory behind the regulations is to make [disposal] less burdensome," explained Rick Brausch of DTSC. "Putting it as universal waste eliminates the testing requirement."

**The fact that cadmium can be washed out of solar modules by rainwater is increasingly a concern for local environmentalists like the Concerned Citizens of Fawn Lake in Virginia, where a 6,350 acre solar farm to partly power Microsoft data centers is being proposed.**

**"We estimate there are 100,000 pounds of cadmium contained in the 1.8 million panels," Sean Fogarty of the group told me. "Leaching from broken panels damaged during natural events — hail storms, tornadoes, hurricanes, earthquakes, etc. — and at decommissioning is a big concern."**

**There is real-world precedent for this concern. A tornado in 2015 broke 200,000 solar modules at southern California solar farm Desert Sunlight.**

"Any modules that were broken into small bits of glass had to be swept from the ground," Mulvaney explained, "so lots of rocks and dirt got mixed in that would not work in recycling plants that are designed to take modules. These were the cadmium-based modules that failed [hazardous] waste tests, so were treated at a [hazardous] waste facility. But about 70 percent of the modules were actually sent to recycling, and the recycled metals are in new panels today."

And when Hurricane Maria hit Puerto Rico last September, the nation's second largest solar farm, responsible for 40 percent of the island's solar energy, lost a majority of its panels.

# Can Solar Producers Take Responsibility?

In 2012, First Solar stopped putting a share of its revenues into a fund for long-term waste management.
**"Customers have the option to use our services when the panels get to the end of life stage," a spokesperson told *Solar Power World*. "We'll do the recycling, and they'll pay the price at that time."**

**Or they won't.** "Either it becomes economical or it gets mandated. " said EPRI's Cara Libby. "But I've heard that it will have to be mandated because it won't ever be economical."

Last July, Washington became the first U.S. state to require manufacturers selling solar panels to have a plan to recycle. But the legislature did not require manufacturers to pay a fee for disposal. "Washington-based solar panel manufacturer Itek Energy assisted with the bill's writing," noted Solar Power World.

The problem with putting the responsibility for recycling or long-term storage of solar panels on manufacturers, says the insurance actuary Milliman, is that it increases the risk of more financial failures like the kinds that afflicted the solar industry over the last decade.

Any mechanism that finances the cost of recycling PV modules with current revenues is not sustainable. This method raises the possibility of bankruptcy down the road by shifting today's greater burden of 'caused' costs into the future. When growth levels off then PV producers would face rapidly increasing recycling costs as a percentage of revenues.

Since 2016, Sungevity, Beamreach, Verengo Solar, SunEdison, Yingli Green Energy, Solar World, and Suniva have gone bankrupt.

The result of such bankruptcies is that the cost of managing or recycling PV waste will be born by the public. "In the event of company bankruptcies, PV module producers would no longer contribute to the recycling cost of their products," notes Milliman, "leaving governments to decide how to deal with cleanup."

Governments of poor and developing nations are often not equipped to deal with an influx of toxic solar waste, experts say. German researchers at the Stuttgart Institute for Photovoltaics warned that poor and developing nations are at higher risk of suffering the consequences.

> Dangers and hazards of toxins in photovoltaic modules appear particularly large in countries where there are no orderly waste management systems... Especially in less developed countries in the so-called global south, which are particularly predestined for the use of photovoltaics because of the high solar radiation, it seems highly problematic to use modules that contain pollutants.

The attitude of some solar recyclers in China appears to feed this concern. "A sales manager of a solar power recycling company," the *South China Morning News* reported, "believes there could be a way to dispose of China's solar junk, nonetheless."

"We can sell them to Middle East... Our customers there make it very clear that they don't want perfect or brand new panels. They just want them cheap... There, there is lots of land to install a large amount of panels to make up for their low performance. Everyone is happy with the result."

In other words, there are firms that may advertise themselves as "solar panel recyclers" but instead sell panels to a secondary markets in nations with less developed waste disposal systems. In the past, communities living near electronic waste dumps in Ghana, Nigeria, Vietnam, Bangladesh, Pakistan, and India have been primary e-waste destinations.

According to a 2015 United Nations Environment Program (UNEP) report, somewhere between 60 and 90 percent of electronic waste is illegally traded and dumped in poor nations. Writes UNEP:

> Thousands of tons of e-waste are falsely declared as second-hand goods and exported from developed to developing countries, including waste batteries falsely described as plastic or mixed metal scrap, and cathode ray tubes and computer monitors declared as metal scrap.

Unlike other forms of imported e-waste, used solar panels can enter nations legally before eventually entering e-waste streams. As the United Nation Environment Program notes, "loopholes in the current Waste Electrical and Electronic Equipment (WEEE) Directives allow the export of e-waste from developed to developing countries (70% of the collected WEEE ends up in unreported and largely unknown destinations)."

**All of that waste creates a large quantity of material to track,**
which in turn requires
coordinated, overlapping, and different responses at the international, national, state, and local levels.

**The local level is where action to dispose of electronic and toxic waste takes place,** often under state mandates. In the past, differing state laws have motivated the U.S. Congress to put in place national regulations. Industry often prefers to comply with a single national standard rather than multiple different state standards. And as the problem of the secondary market for solar shows, ultimately there needs to be some kind of international regulation.

**The first step is a fee on solar panel purchases to make sure that the cost of safely removing, recycling or storing solar panel waste is internalized into the price of solar panels and not externalized onto future taxpayers**. An obvious solution would be to impose a new fee on solar panels that would go into a federal disposal and decommissioning fund. The funds would then, in the future, be dispensed to state and local governments to pay for the removal and recycling or long-term storage of solar panel waste. The advantage of this fund over extended producer responsibility is that it would insure that solar panels are safely decommissioned, recycled, or stored over the long-term, even after solar manufacturers go bankrupt.

**Second, the federal government should encourage citizen enforcement of laws to decommission, store, or recycle solar panels so that they do not end up in landfills.**

**Currently, citizens have the right to file lawsuits against government agencies and corporations to force them to abide by various environmental laws, including ones that protect the public from toxic waste. Solar should be no different.**

**Given the decentralized nature of solar energy production, and lack of technical expertise at the local level, it is especially important that the whole society be involved in protecting itself from exposure to dangerous toxins.**

**Lack of technical expertise** can be a problem when solar developers like Sustainable Power Group, or sPower, incorrectly claim that the cadmium in its panels is not water soluble. That claim has been contradicted by the previously-mentioned Stuttgart research scientists who found cadmium from solar panels "can be almost completely washed out...over a period of several months...by rainwater."

# CADMIUM (Cd)

**Cadmium** Telluride (CdTe) **is a** commonly used material in thin film **solar modules. Cadmium is a** heavy metal and extremely dangerous. ... In relation to **solar panels, the** CdTe is safe while encapsulated in **the** module, but if **the panel** is damaged and exposed to water, **the cadmium** telluride could leach into **the** water. Apr 21, 2011

**During manufacture and after the disposal of solar panels, they release hazardous chemicals including cadmium compounds, silicon tetrachloride, hexafluoroethane and lead.**

Cadmium Telluride. ...

Copper Indium Selenide. ...

Cadmium Indium Gallium (Di)selenide. ...

Silicon Tetrachloride.

Apr 30, 2018

**Cadmium** and **cancer. Cadmium** is an established human and animal carcinogen. Most evidence is available for elevated risk for lung **cancer** after occupational exposure; however, associations between **cadmium** exposure and tumors at other locations including kidney, breast, and prostate may be relevant as well.

**Cadmium** has many uses, including in the production of batteries, pigments, metal coatings, and plastics. **Cadmium** and its compounds are highly toxic and exposure is known to **cause cancer**. It is primarily associated with human lung, prostate, and kidney **cancers**, and recently pancreatic **cancer**.

**Cadmium** is also an environmental hazard. Human exposure is primarily from fossil fuel combustion, phosphate fertilizers, natural sources, iron and steel production, cement production and related activities, nonferrous metals production, and municipal solid waste incineration.[4] Bread, root crops, and vegetables also contribute to the cadmium in modern populations.[65]

**Solar panels** contain lead, cadmium, and other **toxic** chemicals that cannot be removed without breaking apart the entire **panel**. ... China has more **solar** power plants than any other country, operating roughly twice as many **solar panels** as the United States and also has no plan for the disposal of the **old panels**. Dec 23, 2018

## Can you get cancer from solar panels?

Yes, UV radiation is a known carcinogen, but **solar panels do** not increase the amount of UV rays that hit a given area. ... **We** don't know enough about **solar panels** to say for sure that they don't cause **cancer**. The radiation that comes from **solar panels** seeps into your home and heightens the risk of **cancer**. Mar 4, 2016

All electrical and electronic device create electromagnetic fields or EMF around them when used and also **emit** electromagnetic **radiation** or EMR. This includes **solar panels** and **solar** inverters. So is it possible for the electromagnetic fields or **radiation** from your rooftop **solar** system to harm you or your family? Nov 27, 2017

3. <u>Toxicity of Cadmium</u>

**Cadmium is one of the top 6 deadliest and toxic materials known.**
However, CdTe appears to be less toxic than elemental cadmium, at least in terms of acute exposure.

**This is not to say it is harmless. Cadmium telluride is toxic if ingested, if its dust is inhaled, or if it is handled improperly** (i.e. without appropriate gloves and other safety precautions). The toxicity is not solely due to the cadmium content. One study found that the highly reactive surface of cadmium telluride quantum dots triggers extensive reactive oxygen damage to the cell membrane, mitochondria, and cell nucleus. In addition, the cadmium telluride films are typically recrystallized in a toxic compound of cadmium chloride.

# copper indium gallium selenide (CIGS) cells

The CIGS cells leached several metals, including molybdenum, zinc, aluminum, selenium, and cadmium. In particular, the team predicts that damaged CIGS cells would release amounts of cadmium leading to environmental concentrations that exceed World Health Organization safe drinking water limits in all the scenarios they tested, with concentrations more than 50 times higher than the limit set for acidic rainwater in arid climates.

## Scale and Market for CIGS

While CIGS has good efficiencies for a thin film PV, it has been unable to overcome crystalline silicon PV. This is primarily due to an expensive manufacturing process and the economic downturn that significantly effected the photovoltaic sectors. With the recent capacity expansions and an increasing market for CIGS, investments are beginning to be made. NanoMarkets expects that CIGS produced for the PV market will grow from $613.4 million in 2011 to $5.41 billion in 2018. It is critical, however, for CIGS manufactures to develop less expensive processes and cheaper substrates in order to complete with conventional crystalline silicon in the PV market. [5]

The following outlines the current production processes for the most prevalent CIGS producing companies:

Solibro - Co-evaporation CIGS process: Process which produces modules with a 17.4% power conversion efficiency[6] [7]

MiaSole - CIGS is deposited on a flexible stainless steel substrate entirely by continuous sputtering in a vacuum[8] to produce modules with an efficiency of 9-10%[9]

Solyndra - Co-evaporation process in which Cu, In, Ga, Se are deposited straight onto glass tubes to produce modules with an efficiency of 7-10%[10]

Global Solar - Co-evaporation CIGS process[11]: Uses an inline three stage deposition process[12] to produce modules with up to 19.9% efficiency in laboratory samples and 10.5%-11% average efficiency in production cells[13]

Soltecture - Co-evaporation process[14] to produce modules with an efficiency up to 13% and an average efficiency of 12%[15]

Nano Solar - Nanoparticle ink is used to print the semiconductor onto a flexible substrate[16] to produce modules with an efficiency of 8-9%[17]

NanoMarkets has identified three markets in which CIGS will be able to make a strong standing: the conventional panel market, rigid and flexible building integrated photovoltaics (BIPV), and the mobile market.

Thin-film market share is stagnated at around 15 percent, leaving the rest of the PV market to conventional solar cells made of crystalline silicon. In 2013, the market share of CIGS alone was about 2 percent and all thin-film technologies combined fell below 10 percent.[2] CIGS cells continue being developed, as they promise to reach silicon-like efficiencies, while maintaining their low costs, as is typical for thin-film technology.[3] Prominent manufacturers of CIGS photovoltaics were the now-bankrupt companies Nanosolar and Solyndra.

# SOLAR COMPANY MANUFACTURERS & UN-SUSTAINABLE BANKRUPTCIES AND FAILING COMPANIES

This list of notable **companies manufacturing** copper indium gallium selenide solar cells **(CIGS)** includes a number of companies, some of which have significantly reduced or completely closed down production:

Ascent Solar Technologies - Annual Revenue 215,000

Flisom (founded in 2005 as a spin-off company of ETH Zürich, Switzerland)

Global Solar Energy (module producer, US-based subsidiary of Hanergy)

Hanergy-Solibro (former subsidiary of Q-Cells)

IBM

International Solar Electric Technology

Manz (turnkey CIGS fab)

Miasolé

Siva Power

Solar Frontier (subsidiary of Showa Shell Sekiyu)

Veeco Instruments Inc

**Former companies**

HelioVolt - BANKRUPT 2014 - 200 MILLION

Nanosolar - OUT OF BUSINESS

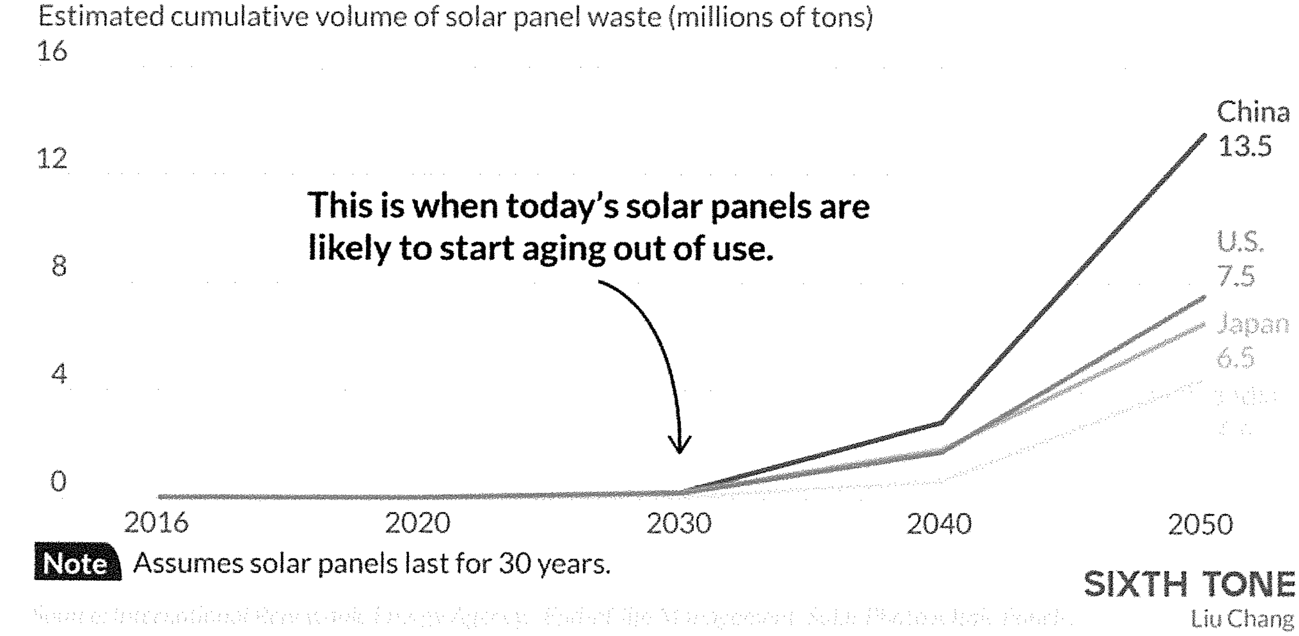
Odersun - BANKRUPT - OUT OF BUSINESS

Soltecture (previously Sulfurcell) - BANKRUPT 2012

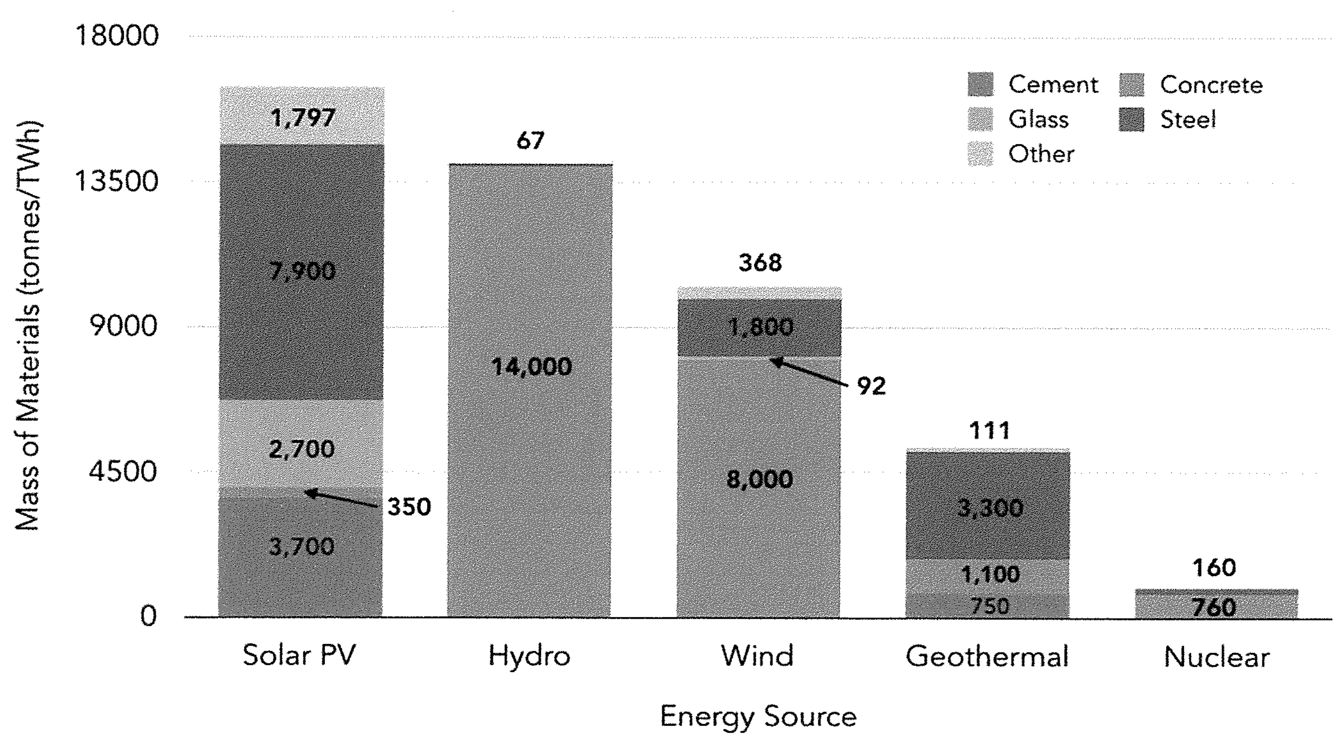
Solyndra - OUT OF BUSINESS - BANKRUPT STOLE 535 MILLION $ LOAN GUARANTEE

TSMC Solar (module producer, wholly owned subsidiary of Taiwanese TSMC)[1][2] - BANKRUPT 2015

# How China's Solar Panel Waste Stacks Up




# Materials throughput by type of energy source




ENVIRONMENTAL PROGRESS

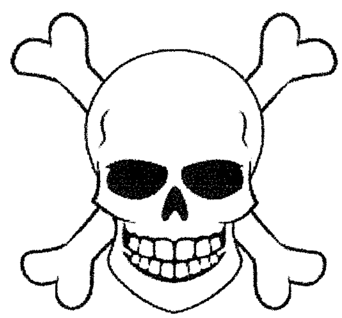
"Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities." Table 10. September 2015. United States Department of Energy. Nuclear and hydro require 10 tonnes/TWh and 1 tonne/TWh of other materials, respectively, but are unable to be labeled on the graph.

What **can cause solar panels** to catch **fire**? ... Incorrectly installed or defective DC/AC inverters have also been known to **cause photovoltaic fires**. Another possible, but rare, hazard is the voltage fluctuations created when excess electricity created by the **solar panels** is sent to the National Grid. Aug 24, 2017

# Inhalation hazards

## (This is nasty smoke)

- You MUST use SCBA when dealing with fire involving PV arrays
  - Treat it like the Hazmat call it is
- PV cells can produce three main chemicals when burning:
- Cadmium Telluride (usually on commercial or utility scale installations)
  - Carcinogenic
- Gallium Arsenide
  - Highly toxic and carcinogenic
- Phosphorous
  - The worst of the three
  - Lethal dose is 50 mg



### WHAT IS THE EMERGENCY EVACUATION PLAN IN CASE OF FIRE?

#### WHY WOULD THIS BE NECESSARY?

ACCORDING TO MANY FIRE SAFETY REQUIREMENT SOURCES A FIRE WOULD MELT OR DAMAGE THE ENCAPSULATION PART OF THE PANEL AND RELEASE THE HAZARDOUS TOXIC AND CANCER CAUSING CHEMICALS INTO THE ATMOSPHERE, WHICH IN THE FORM OF GASES AND VAPORS WOULD BE CARRIED BY THE WINDS OR BLOWING BREEZES SIGNIFICANT DISTANCES WHICH COULD AND WOULD HAVE SERIOUS CONSEQUENCES TO THOSE PEOPLE IN THE COMMUNITY WHO INHALE THE INVISIBLE GASES AND CHEMICAL FILLED SMOKE AS WELL AS THE FIRST RESPONDERS AND FIREFIGHTERS TRYING TO PUT THE FIRE OUT. CHEMICAL FIRES ARE DIFFICULT TO PUT OUT AND CANT BE PUT OUT BY WATER, IN MOST CASES IF NOT ALL, A CHEMICAL RETARDANT IS NECESSARY TO EXTINGUISH THE FIRE. THE SHUTTING OFF OF POWER TO THE PANELS IS NOT AN OPTION SINCE THE POWER IS CONTINUOSLY POWERED ON WHICH PUTS FIRST RESPONDERS AND FIREMAN AT RISK OF ELECTROCUTION AND EXPOSURE TO THESE TOXINS.

**LONG ISLAND CONTINGENCY PLAN FOR EMERGENCIES - NATURAL DISASTERS AND MAN CAUSED DISASTERS**

HOW WILL YOU PROTECT OUR WATER SUPPLY, SOIL CROPS , AND PEOPLE FROM THESE HAZARDOUS TOXIC CHEMICALS?

**CAN YOU 100% GUARANTEE**

THAT NO CHEMICALS WILL EVER ENTER OUR SOIL, GROUNDWATER, RUNOFF INTO WETLANDS, OR CROPS?

IF YOU CANT GUARANTEE 100% SAFETY FROM THESE HAZARDS - WHY ARE WE STILL TALKING ABOUT THIS?

**NATURAL DISASTERS - POTENTIAL DAMAGE TO PANELS**

1. HURRICANES (HIGH WINDS, BROKEN BRANCHES, FLYING DEBRIS)
2. HAIL (ANY SIZE CAN DAMAGE PANELS)
3. TORNADOS (RARE BUT POSSIBLE)
4. FLOODING (FLOATING DEBRIS, SALT AIR AND WATER CORROSION)
5. FIRE (PINE BARRENS, BRUSH FIRE, POWER OVERLOAD, SPARKS CAUSED BY BIRD WINGS TOUCHING TWO CABLES )
6. LIGHTNING STRIKES CAN CAUSE FIRES AND/OR PUNCTURE THE PANELS (CAUSING CHEMICAL LEAKAGE) AS IT STRIKES AND PASSES THROUGH
7. SNOW AND ICE STORMS - MELTING SNOW - SALT AND SAND SPRAY FROM PLOWING SNOW.
8. FREEZING TEMPS MAY CRACK PANELS CAUSING CHEMICAL LEAK
9. BIRD DROPPINGS (ACIDIC AND CORROSIVE) AND BIRD STRIKES AS FEATHERS ARE SYNGED BY INTENCE HEAT OF SOLAR ARRAY
10. MIGRATORY BIRDS CRASHING INTO PANELS THINKING IT IS A POND OR LAKE AS IT LOOKS LIKE WATER FROM ABOVE.
11. TIME - CORROSION BY SALT AIR, ACID RAIN, RUST, DUST AND DIRT, DECOMPOSITION, WEAR AND TEAR ON MECHANICAL (MOVABLE) PARTS

**MAN –MADE CAUSES - POTENTIAL DAMAGE TO PANELS**

1. FIRES (ARSON, TERRORIST ACTIVITIES, ACCIDENTS, CIGARETTES, ENEMY ATTACK FROM THE AIR TO TAKE OUT GRID, ETC)
2. ACCIDENTS - PLANE CRASHES, CAR CRASHES, DRONE CRASHES, SATELLITE OR SPACE DEBRIS
3. VANDALISM - ROCK THROWING AND OTHER FORMS OR PHYSICAL DAMAGE TO PANELS
4. OPEN TO POSSIBLE RANSOM / BLACKMAIL THREATS TO DAMAGE OUR WATER SUPPLY / SOIL UNLESS A RANSOM IS PAID BY TOWN
5. MAINTENANCE, REPAIRS , AND/OR REPLACEMENT OR PANELS OR SYSTEM ITSELF THAT MAY LEAD TO ACCIDENTS
6. DISMANTLING AND DISPOSAL OF PANELS - HAZARDOUS TOXIC WASTE REMOVAL AND CLEANUP
7. DAMAGE CAUSED BY CLEANING PANELS WITH SOLVENTS AND WATER PRESSURE
8. RUNOFF OF WASH WATER SEAPING INTO ANY CRACKS OR OPENINGS THAT MAY FREEZE AND EXPAND IN WINTER TIME
9. WEAR AND TEAR ON MECHANICAL (MOVEABLE) PARTS INCLUDING PETROLEUM PRODUCTS USED FOR LUBRICATION
10. PETROLEUM AND CLEANING SOLVENTS RUNOFF OF WASHED MATERIAL INTO SOIL AND EVENTUALLY INTO GROUND WATER.
11. PLUS ANY UNTHINKABLE OR UNIMAGINABLE CAUSES NOT STATED ABOVE INCLUDING NEGLIGENCE DUE TO BANKRUPCY .
12. WHO WILL BE RESPONSIBLE FOR CLEANUP, DISMANTLING, AND DISPOSAL OF PANELS IF NO LONGER IN BUSINESS AT TIME.