# OSH AND SMALL-SCALE SOLAR ENERGY APPLICATIONS

## 1 Introduction

Small-scale and domestic solar energy installations are widely used but only scant attention has been given to the associated occupational safety and health (OSH) aspects so far. From their manufacturing, transport, installation and maintenance to decommissioning and recycling, many different workers' groups in various types of workplaces and sectors are involved with such systems. It is therefore important to give enough consideration to OSH when such applications are designed and planned in order to avoid OSH risks to occur later at one stage of their life cycle. This e-fact aims at raising awareness for the work-related risk factors and OSH issues associated with domestic and small-scale solar energy installations across their life cycle.

Author: David Tijero Osorio

### 1.1 Technological basis and application of small-scale solar installations

Two types of technologies make use of the sun's energy: solar photovoltaic (PV) and solar thermal power (STP). Neither of them produces greenhouse gases or toxic gas emissions in use and both are appropriate for small-scale applications. Concentrated solar power (CSP) is used only for large-scale applications.

Photovoltaic systems are the most common and use cells to convert solar radiation into electricity. The sunlight creates an electric field across the layers of a semiconducting material, producing an electric direct current. A power inverter transforms the direct current into alternating current. The conversion of radiation is based on a physical effect and cannot be switched off.

The most common semiconductor material used in photovoltaic cells is silicon. The manufacturing processes and materials are similar to those in the microelectronics industry. At the leading edge are 'thin-film' cells, using very small amounts of semiconductor materials, applied in thin layers to glass, metal and plastic surfaces. Materials used for PV technology include crystalline silicon (x-Si), amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium diselenide (CIS) and copper indium gallium disulphide (CIGS).

Most small-scale PV facilities are connected to the power supply system. The systems can be built as rooftop installations on houses, apartment buildings or commercial buildings. PV materials can also be building integrated (BIPV), e.g. into house fronts or roof claddings.

Solar thermal or solar water heaters convert sunlight into heat. They comprise flat plate collectors with a water/glycol mixture as heat transfer fluid. The heat is transported to a storage tank and can be used for hot water generation or heating. Unlike PV, STP does not use toxic, explosive, corrosive or potentially carcinogenic materials and the system does not feature electrical hazards.

### 1.2 Political targets

The European Union (EU) has an ambitious strategy for climate and energy policy that aims to combat climate change, increase energy security and transform Europe into a low-carbon economy. To boost this process the European Commission (EC) set a target of cutting $CO_2$ emissions by at least 20%

from its 1990 emission levels by 2020 and increasing the renewable energy component of all primary energy consumed by 20%.

Solar energy plays a major role in a sustainable energy mix within Europe, with the Commission investing in boosting solar energy. Within the Strategic Energy Technology (SET) Plan, a European Industrial Initiative on solar energy has been established to enable solar technologies to be clean, competitive and sustainable technologies providing up to 15% of European electricity demand by 2020.

Solar energy technologies are generally more labour intensive than conventional technologies, such as fossil fuel-based technologies, so that the EU's push for solar energy influences a structural shift in employment and creates large numbers of jobs in solar energy.

### 1.3 Role and impact of solar energy

The growth of the solar sector has been rapid during the last two decades and this trend is likely to continue. The reduction in the costs of solar energy systems, with the availability of public funding and investment, is leading to a high demand for domestic installations. Europe's substantial investment in solar power is reflected in the 320,000 employees in the sector in 2011, an increase of 86% from 2009 [1].

The solar electric capacity from PV in all Member States amounted to 26 gigawatts (GW) in 2010 and it is projected to increase to 84 GW by 2020. The average annual growth for capacity of solar electricity was 64% in 2005–2010. The projected average annual growth for energy from solar thermal features a steady growth of 16% over the period 2005–2020, but still has a considerably lower share than solar electricity [2].

Europe's solar market is slowing in the flagship countries, for example Germany and Spain, mainly because of reducing government support. By contrast, some smaller markets in Central and Eastern Europe are growing rapidly, for example Austria, Belgium, Ukraine, Bulgaria, the Czech Republic and Romania. These countries increasingly offer incentives such as fixed feed-in tariffs and tax breaks. A more homogeneous dissemination of solar energy throughout the EU can result in the near future.

## 2 OSH along the life cycle of small-scale solar systems

The life cycle of small-scale solar installations includes the following stages: design and planning, fabrication, transportation, installation, integration with the infrastructure, operation and maintenance, dismantling and finally disposal/recycling. These stages involve different worker's groups in various types of workplaces and sectors, for example industrial machinery mechanics, electrical engineers, welders, metal workers, electricians, installers of solar energy systems, construction workers, waste management workers, etc. [3].

The consideration of OSH aspects across these stages shows that the main hazards – hazardous substances, working at height, slips, trips and falls, electric and fire hazards – may therefore have an impact on numerous workers in numerous workplaces. When designing a solar array, it is therefore important to consider OSH over the entire life cycle of the system and to design the system so as to minimise the OSH risks in later stages of the life cycle. Before putting the product on the market, OSH performance testing is also necessary to ensure that the product meet acceptable OSH standards.

The majority of the hazards related to small-scale solar systems are basically known from other industries and can be managed with existing OSH knowledge. However, novel combinations of skills are also required to meet new constellations of hazards and to deal with new products (e.g. PV tiles, meaning that tiles become a source of electrical hazard) and substances such as novel nanomaterials. Solar hot water installations, for example, require workers to have the skills of a roofer, a plumber and an electrician, as well as knowledge of working at height.

The rising demand for small-scale, domestic solar installations may also lead to a skills gap that might be difficult to fill promptly; and may in turn result in workers handling new technologies, or technologies with which they are not familiar, while lacking the adequate training and skills to do so [4]. In addition, the availability of public funding to encourage such installations may attract new companies that may lack experience in this area. And the rush to benefit from such subsidies before their possible withdrawal could draw attention away from OSH.

There are currently no reliable data on work-related accidents linked to solar energy systems. As much of the work in relation to the installation of such systems is done by self-employed or within the informal economy, collecting data on work-related accidents and diseases is challenging. The workplace risk assessment may also be hampered by a lack of safety and health data available, especially on the broad range of solar technologies and manufacturing processes of photovoltaic cells. The data available on fatal falls from height would indicate that rooftop solar power is several times more dangerous than wind power or nuclear power (0.44 deaths per terawatt hour each year compared with 0.15 and 0.04 deaths respectively) [6]. As the demands for small-scale solar installations increase, the probability of health and safety-related accidents may also be rising.

The expansion of the solar sector gives rise to a substantial upscaling of all stages of the technology's life cycle with potential risks for an increased number of people. Once the PV panels reach the end of their life cycle, they will create a huge amount of electronic waste (e-waste) with potential environmental and health impacts. Other life cycle phases of the solar technologies such as construction and maintenance are also affected by upscaling and must be closely monitored with regard to OSH aspects. The hazards of new solar PV technologies (solar cells with organic semiconductors, dye-sensitised cells, thin-film microcrystalline silicon carbide cells, and cells made of nanomaterials) are difficult to evaluate since they are still at the laboratory stage of development [5].

## 2.1 OSH risks associated with the manufacture of solar installations

In manufacturing PV cells, the health of workers may be adversely affected by a variety of chemicals and materials. Chemical hazards are related to the materials' toxicity, corrosivity, flammability and explosiveness. The amounts and types of chemicals used vary depending upon the type of cell being produced, whereas the semiconductor materials themselves are used in small quantities, especially in the production of ultra-thin layers [7]. Additionally, the solder joints between the panels may contain heavy metals such as lead.

Particularly hazardous in the manufacture of x-Si cells are caustic chemicals such as hydrofluoric acid (HF) used to clean the silicon wafers, and silane gas ($SiH_4$), which is extremely flammable and explosive. At present, much of the silicon used as the basic material for x-Si cells is produced in countries such as China where OSH standards vary. Producing a-Si cells also requires the use of large amounts of $SiH_4$. The major hazard regarding CdTe cells is the toxicity and carcinogenicity of cadmium. CdTe appears to be less toxic than elemental cadmium, at least in terms of acute exposure [8]. The use of hydrogen selenide ($H_2Se$) presents the main problem associated with CIS/CIGS cells; sparse information exists on the toxicity of CIS [9]. The handling of the above-mentioned chemicals in the semiconductor industry is routine, and safety measures are mostly established. Safe work procedures and the deployment of closed manufacturing systems or ventilation systems and fume cupboards minimise risks of exposure.

Manual handling issues have to be considered during the manufacturing processes, especially when there are increases in the magnitude of products that require manual handling [10]. Prevention options could include the use of adjusted ergonomic solutions, such as vacuum lifting devices and the implementation of automation and robotics. Assembly tasks requiring repetitive movements of the upper limbs (arms and hands) are a common risk factor for the development of upper limb disorders (ULDs).

The transport of (parts of) small-sized solar energy installations from the factory to the customer site is not critical but should follow the OSH regulations that otherwise apply to the transport of goods.

## 2.2 OSH risks associated with installation, maintenance and decommissioning

The main hazards are associated with working at height and include: access issues; falling objects; falls, slips, and trips caused for example caused by slippery glazed tiles or tiles with algae or moss deposits on roof surfaces; large roof pitches; fragile roofs; and brittle or damaged roofing. In addition to the risk of injury from slips, trips and falls, these hazards may also contribute to musculoskeletal disorders (MSDs). For example, solar panels, especially hot water panels, can be heavy and difficult to lift onto rooftops. Working in awkward postures for longer periods, including kneeling and squatting, is also frequently required, which means that workers are exposed to ergonomic risks during (de)installations and maintenance activities that may result in musculoskeletal disorders, such as back injuries.

Adverse weather conditions such as extreme temperatures present further risks such as cold or heat stress. Exposure to sun radiation may lead to sunburns, eye disorders and certain types of cancers. Rain or snow may result in slippery surfaces and lead to slips and falls.

Solar thermal installations do not exhibit electrical dangers, but could cause burns or scalding due to hot fluids, while PV systems may present electrical risks. First, working near overhead power lines, which follow roof stands, poses a threat. Second, PV systems present electrical risks if the electrical system is compromised or the protective coverings on the components are damaged. The typical voltage, in the range of 600 volts, can cause electrical shocks (electrocution) or electrical, thermal and arc burns [11]. Furthermore, even low amperage levels can cause an involuntary muscle reaction, which could trigger a fall from a roof. An additional challenge is that the PV system is always powered because of solar radiation and cannot be shut off for maintenance or other work on the system. New electrical risks could also emerge alongside technology developments. For example, photovoltaic cells can be built into tiles, prompting roofers to install them without electrical training.

The requirements for (de)installing and the upkeep of residential or business solar systems are complex and call for various types of knowledge, which implies that any subcontracting should involve workers with a combination of skills across different sectors. The lack of such skilled workers, together with the strong focus on obtaining subsidies, contributes to the frequent employment of unskilled workers, migrant workers with poor knowledge of their host country's language, and illegal work. Precarious working conditions due to time or cost pressure can cause elevated stress levels. Considering this, it is crucial to foster communication along the subcontracting chain and to intensify the adherence to OSH standards of all subcontractors.

As the complexities of installation are reduced, unregulated private occupant installations can become more common, for example as self-installed kits can be purchased from a local hardware store. Therefore, monitoring of the installation process by OSH professionals may be required to assure safe installations and guarantee the safety of occupants, maintenance workers and emergency first responders [12].

## 2.3 OSH risks related to integration into infrastructure and operation

The integration of domestic and other small solar systems into the power network and the operation of the system entail electrical hazards and fire risks similar to those of installation and maintenance. There is no danger due to hazardous substances, gases or chemicals during the normal operation of PV modules, as it is impossible for any vapours or dust to be generated.

Qualified workers would normally connect solar panels to the mains. However, building owners, tenants, company holders or caretakers may also attempt to do this work themselves without having the required skills, thereby putting themselves at risk. Besides the connection work, they may also attempt themselves other activities, such as cleaning, checking the surfaces and the mounting, inspecting the electric control and the inverter etc., for which they may not be adequately trained either. If they contract workers to do the connection work and these further tasks, because they are themselves unaware of the risks and of the need to be qualified, they may contract unskilled workers, thereby likewise putting them at risk.

## 2.4 OSH risks associated with waste management and recycling

Modules are expected to last about 30 years, after which they will have to be decommissioned and disposed or reused, as with other electronic products. Recycling PV systems at the end of their life is environmentally preferable, as 95% of semiconductor material and 90% of glass can be recycled [13]. Separating the hazardous metals from glass and metal frames allows a reduction in hazardous waste by three orders of magnitude [14].

The expected uptake in recycling poses potential workplace health and safety concerns for recycling companies and their workers during waste collection and processing of recyclables. As with manufacturing, workers can be exposed to semiconductor materials or heavy metals from the solar panels they are disassembling. Similarly, they are confronted with ergonomic risks and risks of MSDs during the handling of heavy modules or repetitive handling. As recyclables are increasingly being collected as a single-stream process with new, more highly mechanised sorting lines, fewer people are required to sort materials by hand. This automation reduces exposure to such hazards.

The waste management of PV systems poses similar hazards to the management of other types of e-waste. All these risks are manageable with the appropriate prevention measures. Increased risks certainly arise when e-waste is sent (illegally) to other countries where good OSH conditions may not be provided and workers are insufficiently protected during handling hazardous waste.

## 2.5 OSH risks to emergency services

In the case of a PV system catching fire, emergency services are confronted not only with electric risks but also, for example, with respiratory hazards from dangerous substances, cave-ins, slips and trips, fall from height, and falling material. Except for electrical risks, the same applies to STP installations. The potential for significant photovoltaic material emissions is negligible since the flame temperatures in roof fires are significantly lower than the evaporating temperatures of the PV materials [9], As with any structural fire attack, optimal assessment is essential. The information that the building has a solar power system and the type of system should be immediately conveyed to the fire fighters to determine subsequent steps according to the guidelines for fire operations [15]. An additional consideration is that fire services often tackle house fires by breaking in through the roof. If there are PV panels obstructing access this could complicate operations.

# 3 Prevention

The risks associated with domestic solar energy systems are basically conventional. However, they are varied, could be combined, could involve new products and substances, and arise in new situations with possibly new, unskilled entrants in this sector. A thorough and individually tailored workplace risk assessment process has to be done and is the cornerstone to prevention. As described in the EU Framework Directive ([1]), hazards have to be identified and risks have to be analysed and prioritised. Subsequently, the hierarchy of control measures has to be observed: eliminating or otherwise substituting the hazard, followed by reducing the risks at source to the minimum with engineering controls, organisational control measures and, as a last resort, the application of personal protective equipment.

The solar sector is a highly dynamic branch still gaining momentum with regard to the development of new systems. The application of new technologies, equipment or substances, the implementation of new work practices or procedures, and the consistent change of the workforce demand a dynamic risk management process with regularly reviewed. Once workplace risks have been successfully controlled, the process should not stop. A systematic monitoring and review system must be implemented, as there is always the potential for new hazards to be introduced into workplaces.

[1] Council Directive of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (89/391/EEC). Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:01989L0391-20081211:EN:NOT

Efforts to eliminate or minimise risks early in the design stage should also be strengthened [16]. At the design stage, a multidisciplinary approach that considers OSH aspects all along the life cycle of small-scale solar applications should be adopted [17].

Since workers in numerous sectors and, additionally, non-occupational groups of people may be exposed to risks from small-scale solar installations, it is necessary to create a widely spread safety and health culture integrating various actors such as worker representatives, business leaders, (sub)contractors, fire services and municipalities. The following measures are particularly significant: regular training engaging all persons involved, permanent monitoring of (new potential) hazards, a reduction in the use of toxic materials at the manufacturing stage, proper testing of new materials and processes based on a precautionary approach, and the design of products which allow safe operations all along the life cycle, including the safe recycling of the system.

A checklist accompanying this e-fact is also available at: https://osha.europa.eu/en/publications/e-facts/e-fact-69-hazard-identification-checklist-osh-risks-associated-with-small-scale-solar-energy-applications to help start the hazard identification process and can therefore be a support to start the workplace risk assessment. It also provides examples of prevention measures to help identify and put relevant prevention measures into practice.

## Further information

EC – European Commission. http://setis.ec.europa.eu/technologies/Solar-photovoltaic, http://setis.ec.europa.eu/technologies/Solar-heating-and-cooling

EPIA – European Photovoltaic Industry Association. http://www.epia.org/about-epia/who-is-epia.html

ESTIF – European Solar Thermal Industry Federation: http://www.estif.org/statistics/st_markets_in_europe_2010/

IFA – Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung. http://gestis-en.itrust.de/nxt/gateway.dll?f=templates$fn=default.htm$vid=gestiseng:sdbeng

ILO – International Labour Organisation. http://www.ilo.org/global/topics/green-jobs/lang--en/index.htm, http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_175600.pdf, http://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_152065.pdf

NFPA – National Fire Protection Association, *Fire Fighter Safety and Emergency Response for Solar Power Systems*, Quincy, May 2010. Available at: http://www.nfpa.org/assets/files/pdf/research/fftacticssolarpower.pdf?bcsi_scan_53dc4632274cd1ca=0&bcsi_scan_filename=fftacticssolarpower.pdf

NIOSH – National Institute for Occupational Safety and Health: http://www.cdc.gov/niosh/topics/PtD/greenjobs.html,

http://blogs.cdc.gov/niosh-science-blog/2010/01/green-2/

OPPBTP – La prévention BTP, *Pose De Panneaux Photovoltaïcs – Préparation d'un chantier*, 2e édition, avril 2011. Available at: http://www.oppbtp.fr/thematiques/danger_nuisance_risque/electricite/documentation/pose_de_panneaux_photovoltaiques_preparation_d_un_chantier

OSEIA – Oregon Solar Energy Industries Association, *Solar Construction Safety*, Portland, 12/06. Available at: http://www.coshnetwork.org/sites/default/files/OSEIA_Solar_Safety_12–06.pdf

OSFM – Office of the State Fire Marshal, *Fire Operations for Photovoltaic Emergencies*, Sacramento, November 2010. Available at: http://osfm.fire.ca.gov/training/pdf/Photovoltaics/Fire%20Ops%20PV%20lo%20resl.pdf?bcsi_scan_53dc4632274cd1ca=0&bcsi_scan_filename=Fire%20Ops%20PV%20lo%20resl.pdf

OSHA – US Occupational Safety & Health Administration. http://www.osha.gov/dep/greenjobs/solar.html

PV Cycle – European Association for voluntary take-back and recovering of photovoltaic modules A.I.S.B.L. http://www.pvcycle.org/

UNEP – United Nations Environment Programme – http://www.unep.org/labour_environment/pdfs/green-jobs-background-paper-18–01–08.pdf

## References


[1] Observ'ER, 'The State of Renewable Energies in Europe 11th – EurObserv'ER Report', Paris, December 2011. Available at: http://www.eurobserver.org/pdf/barobilan11.pdf?bcsi_scan_53dc4632274cd1ca=0&bcsi_scan_filename=barobilan11.pdf

[2] Beurskens, L. W. M., Hekkenberg, M. & Vethman P., 'Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States', ECN-E-10-069, 2011. Available at: http://www.ecn.nl/docs/library/report/2010/e10069.pdf

[3] EU-OSHA (European Agency for Safety and Health at Work), 'Foresight of New and Emerging Risks to Occupational Safety and Health Associated with New Technologies in Green Jobs by 2020, Phase I – Key drivers of change', 2011. Available at: http://osha.europa.eu/en/publications/reports/foresight-green-jobs-drivers-change-TERO11001ENN

[4] Department of Health and Human Services, Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH), 'Summary of the Making Green Jobs Safe Workshop', Washington, DC, December 14–16, 2009. Available at: http://www.cdc.gov/niosh/docs/2011-201/pdfs/2011-201.pdf

[5] Silicon Valley Toxics Coalition, 'Toward a Just and Sustainable Solar Energy Industry', White Paper, 2009. Available at: http://svtc.org/wp-content/uploads/Silicon_Valley_Toxics_Coalition_-Toward_a_Just_and_Sust.pdf

[6] Next Big Future, 'Deaths per TWH by Energy Source', 2011. Retrieved 10 September, from: http://nextbigfuture.com/2011/03/deaths-per-twh-by-energy-source.html

[7] EPRI (Electric Power Research Institute), 'Potential Health and Environmental Aspects Associated with the Manufacture and Use of Photovoltaic Cells', Final Report, Palo Alto, 2003. Available at: http://www.energy.ca.gov/reports/500–04–053.PDF

[8] Zayed, J. & Philippe, S., 'Acute Oral and Inhalation Toxicities in Rats with Cadmium Telluride', International Journal of Toxicology, Vol. 28, No 4, 2009, pp. 259–265.

[9] Fthenakis, V. M., 'Overview of Potential Hazards', in Markvart T. & Castaner, L. (Eds.), Practical Handbook of Photovoltaics: Fundamentals and Applications, Elsevier, 2003, pp. 854–868. Available at: http://www.bnl.gov/pv/files/pdf/art_170.pdf

[10] Wang, M-J. J., Chung, H-C. & Wu, H-C., 'Evaluating the 300mm Wafer-Handling Task in Semi-Conductor Industry', International Journal of Industrial Ergonomics, Vol. 34, No 6, 2004, pp. 459–466. Available at: http://ir.lib.cyut.edu.tw:8080/bitstream/310901800/7335/1/A7.pdf

[11] Chen, H., Green and Healthy Jobs, Labour Occupational Health Program, University of California at Berkeley, 2010. Available at: http://www.cpwr.com/pdfs/Green-Healthy%20Jobs%20fnl%20for%20posting.pdf

[12] Grant, C. C., 'Fire Fighter Safety and Emergency Response for Solar Power Systems', Final Report, a DHS/Assistance to Firefighter Grants (AFG) Funded Study, May 2010. Available at: http://www.nfpa.org/assets/files/pdf/research/fftacticssolarpower.pdf?bcsi_scan_53dc4632274cd1ca=0&bcsi_scan_filename=fftacticssolarpower.pdf

[13] Krueger, L., 'An Overview of First Solar's Module Collection and Recycling Program', Presented at Photovoltaics Recycling Scoping Workshop, 34th PV Specialists Conference, June 11, 2009, Philadelphia, USA, and at 1st International Conference on Module Recycling, January 2010, Berlin, Germany. Available at: http://www.bnl.gov/pv/files/PRS_Agenda/2_Krueger_IEEE-Presentation-Final.pdf

[14] Fthenakis, V. M., 'End-of-Life Management and Recycling of PV Modules', Energy Policy, Vol. 28, 2000, pp. 1051–1058. Available at: http://clca.columbia.edu/papers/End_Life_Management_Recycling_Energy_Policy.pdf

[15] CAL Fire (Office of the State Fire Marshal), 'Fire Operations for Photovoltaic Emergencies', November 2010. Available at: http://osfm.fire.ca.gov/training/pdf/Photovoltaics/Fire%20Ops%20PV%20lo%20resl.pdf?bcsi_scan_53dc4632274cd1ca=0&bcsi_scan_filename=Fire%20Ops%20PV%20lo%20resl.pdf

[16] Schulte. P. A., Rinehart, R., Okun, A., Geraci, C. L. & Heidel, D. S., 'National Prevention through Design (PtD) Initiative', Journal of Safety Research, Vol. 39, No 2, 2008, pp. 115–121.

[17] Ertas, A., 'Prevention through Design: Transdisciplinary Process', Lubbock, Texas, 2010. Available at: http://basarab.nicolescu.perso.sfr.fr/ciret/ARTICLES/Ertas_fichiers/ptd.pdf