

Stainless Steel in Solar Energy Use



Stainless Steel in Solar Energy



Table of contents

Thermo-solar systems	2
Stainless steel hot water tanks in direct thermosiphon systems	2
Stainless steel heat exchangers in indirect pressurised systems	5
Glazed stainless steel cushion absorbers	7
Stainless steel frames for solar-thermal panels	9
Unglazed stainless steel roofing panels	10
Organically-coated unglazed stainless steel panels	12
Connectors	13
Photovoltaic cells	14
Flexible PV modules on stainless steel roofs	14
Flat roofs	14
Tilted roofs	16
Architectural integration	17
Fasteners	19
Stainless steel – the sustainable option	21

Harvest the sunshine with stainless steel

Energy is an indispensable pre-requisite for our economies to prosper. However, the use of energy is often associated with pollution and depletion of non-renewable resources. Unless they are addressed properly, environmental factors can limit our future industrial and social development. Reducing our dependence on the classic sources of energy and making energy democratically available to a growing world population are key issues for present and future generations.

Fortunately, nature is generous. It provides liberal amounts of energy. The sun is just one source. The challenge lies in capturing its radiation and transforming, transporting and storing the energy. As in many areas of energy transformation and use, stainless steel plays a key role in solar technology – and has the potential to grow further.

This brochure details current best practice and stainless steel solutions to harness the energy of the sun. It provides designers with information about current stainless steel options for solar energy capture and an overview of the technical properties of stainless steel. Industrial, institutional and private property owners will be encouraged to include solar energy in their building projects. We hope the document will also contribute to an optimistic, pro-active approach to solving today's energy concerns.

Wherever technical solutions are required for key tasks in our modern societies – food production, health care, drinking water preparation – stainless steel is now a normal material. Use of solar energy can now be added to the list. This brochure shows why and how.

Jürgen Fechter

Chairman Market Development Committee
International Stainless Steel Forum



Thermo-solar systems

Thermo-solar systems produce hot water. They are the most wide-spread application of solar energy use. Even in moderate climate zones or colder seasons, state-of-the-art solar installations can provide most of the hot water needs of a building.

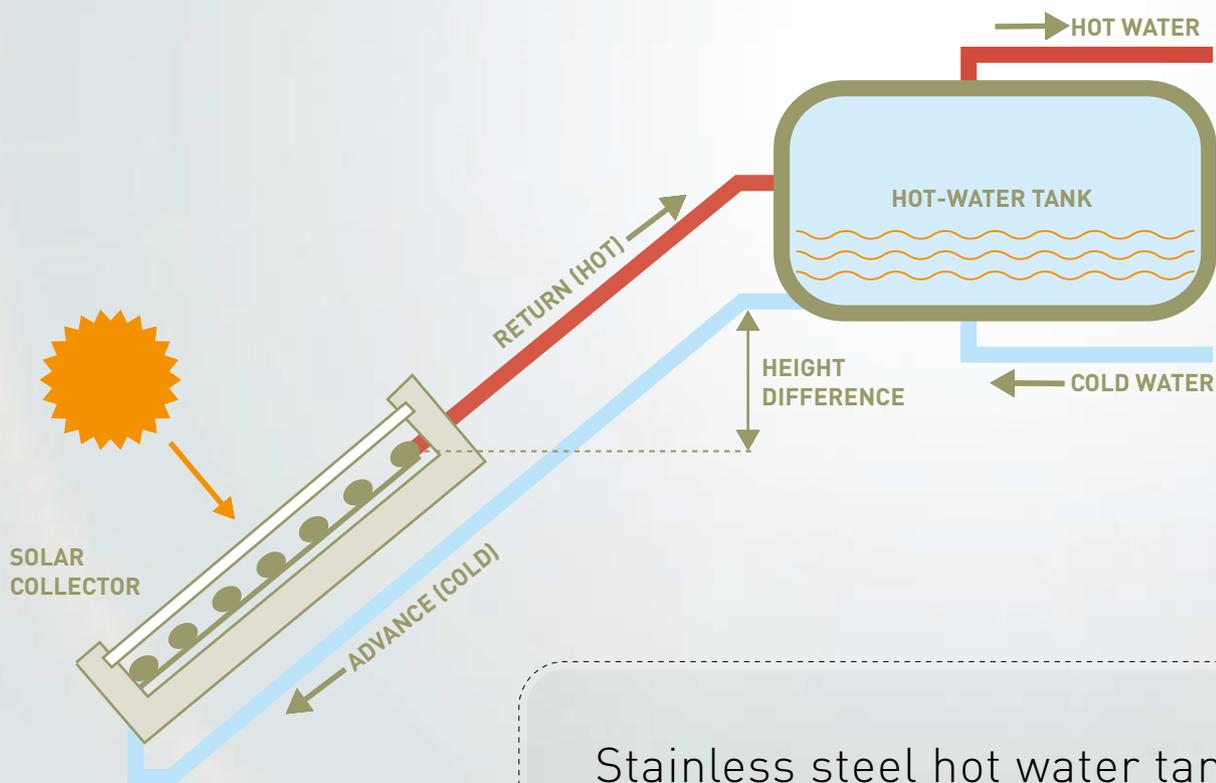


FIGURE 1: The thermosiphon principle

Stainless steel hot water tanks in direct thermosiphon systems

Thermosiphon systems take advantage of the physical phenomenon that hot water is less dense than cold water. The collector consists of black plate which is made of a metal that has high thermal-conductivity. A sling, made of metal tube, is welded or brazed to the plate. The assembly is then covered with a sheet of glass.

The black collector plate absorbs most of the incoming solar radiation. Glazing turns the collector into a kind of greenhouse, trapping the heated air. The thermal energy that is collected is conducted towards the metallic tubes where it heats the water contained inside. As the density of the hot water goes down as temperature increases, the “lighter” hot water rises (via the return) into the hot water tank, where it collects at the top. The natural pump effect makes the colder water at the bottom of the tank flow into the collector.

The repetition of this process gradually heats all of the water in the tank. The heated water is extracted from the top of the tank and used as domestic hot water.

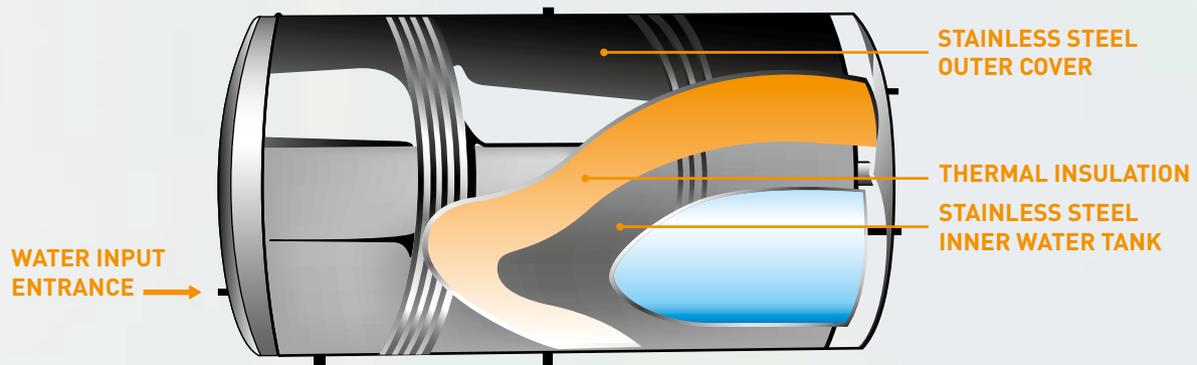


FIGURE 2: Hot water tank with an inner and outer shell in grade 304 stainless steel (Photo: samsung.com.tw)

Direct thermosiphon systems can be used in parts of the world where there is no risk of frost. Thermosiphon systems consist of tanks with an inner and an outer shell (Figure 2). Stainless steel is an excellent candidate material for both. The inner tank is in permanent contact with the domestic hot water, which should have drinking water quality. Hygienic considerations make stainless steel a good choice. Other materials can develop cracks, which may favour the proliferation of germs. Corrosion in these materials may lead to rough surfaces, which are susceptible to the growth of bacteria and adhesion of biofilms. Corrosion can adversely affect the quality of the water. Stainless steel solutions avoid all these problems from the outset.

The outer tank serves as containment for both the hot water tank and the thermal insulation, which reduces heat loss during the night. As it is permanently exposed to the elements, the outer tank should also be resistant to atmospheric pollutants. Stainless steel in the inner and outer shells ensure the hot water tank lasts as long as the installation as a whole (Figure 3).



FIGURE 3: Stainless steel tanks have optimal hygienic properties (Photo: jj-solar.com)



FIGURE 4: Long-term experience in rooftop applications is available all over the world. (Photo: jj-solar.com)



FIGURE 5: Higher-alloyed stainless steel grades are also resistant to coastal atmosphere. The examples shown are situated in locations near the Atlantic coast (Photo: suntank.com)



For the outer tank, stainless steel ensures durability and long-term visual attractiveness. For the inner tank, stainless steel provides its well-known hygiene advantages – a relevant issue in systems that send the water directly into the domestic plumbing system.

Stainless steel heat exchangers in indirect pressurised systems

In areas of the world where frosts occur, indirect systems are a common solution. In contrast to direct systems, which heat the domestic hot water directly, indirect systems involve a fluid that includes a non-freezing agent such as glycol (Figure 6). The fluid circulates in a closed loop (the primary circuit). Heat energy is transferred to the domestic hot water via a heat exchanger.

In larger indirect systems the natural siphon effect may not be strong enough to ensure circulation. A pump is used to maintain the primary circuit. The system is therefore pressurised and needs electrical power to work properly (Figure 7).

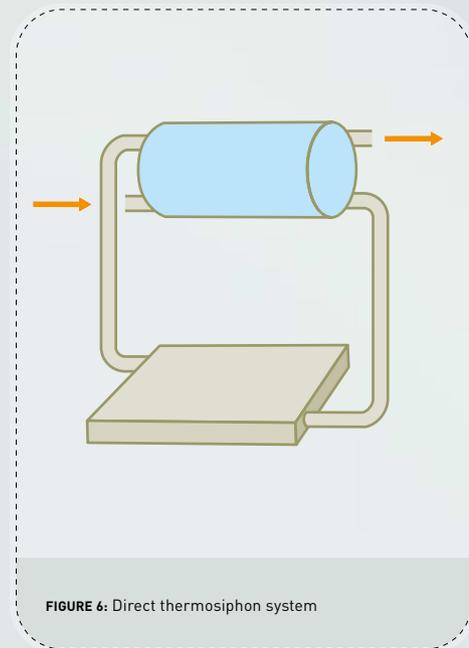


FIGURE 6: Direct thermosiphon system

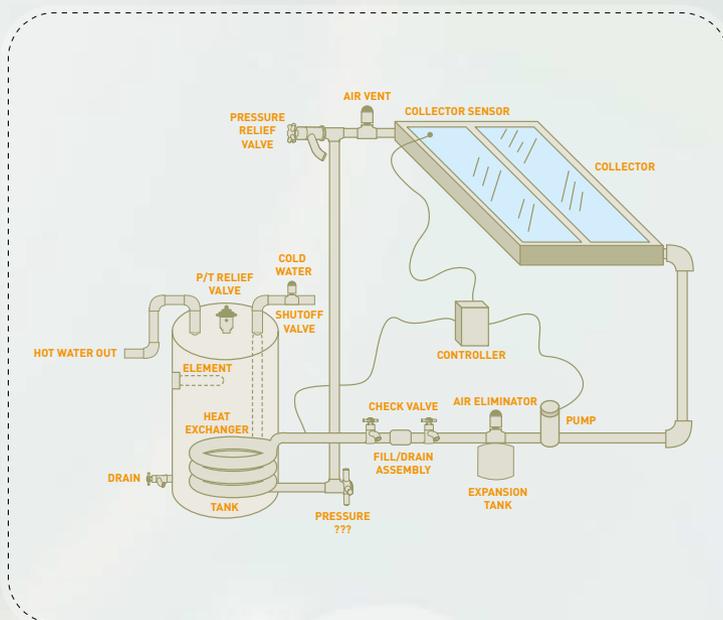


FIGURE 7: Indirect pressurised glycol system

The indirect hot water tank is the usual option in regions with marked differences between the seasons. Other sources of energy (such as conventional oil or gas, biogas or other types of biofuel) are needed to produce domestic hot water during the colder months. Experience shows that in moderate climate zones, the economic optimum is reached when 60% of the overall energy needs for a year are covered by solar panels and 40% by other sources of energy.



FIGURE 8: Hot water tank, exterior view (Photo: rotex.de)

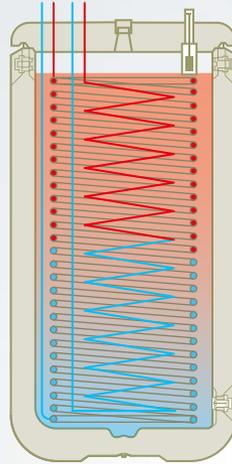


FIGURE 9: The fluid of the primary circuit transfers its heat energy to the domestic hot water through ultra-thin stainless steel tubes (Photo: rotex.de)

The heat exchanger principle (Figures 8-10) also prevents deposits from building up in the collector. Lime or other particles are often found in tap water. They may accumulate in the pipes and eventually reduce the efficiency of the system.



FIGURE 10: Cut-away showing the hot water tank design (Photo: rotex.de)

To facilitate heat transfer, the wall of the tube must be as thin as possible. Owing to its excellent mechanical properties, stainless steel pipes can have walls that are as thin as 0.3 mm. Corrugations give the tube the necessary mechanical resistance to withstand working pressures of up to 6 bar and even survive test pressures of 30 bar without breaking (Figure 11).



FIGURE 11: Corrugated stainless steel tube (witzenmann.com)

Being in contact with potable water, the tube must also meet high hygienic requirements. Here again, stainless steel (a standard choice for heat exchangers in the food and beverage industries) is a preferred material.

Both from hygiene and performance perspectives, stainless steel is the optimal material for heat exchangers in hot water tanks.

Glazed stainless steel cushion absorbers

Glazed solar collectors are the most common type of solar panels. They generate a greenhouse effect in the void between the glass cover and the absorber which traps the thermal energy. The highest efficiency is reached when the solar radiation hits the panel at a right angle. The more the angle deviates from 90 degrees, the more the yield decreases because higher and higher proportions of the radiation are reflected by the glass. The strength of this effect is also dependent on the chemical composition and surface of the glass. Special anti-reflex glass can significantly reduce unwanted reflection.

Conventional absorbers involve coated panels of metallic materials with elevated thermal conductivity. The thermal energy is collected and transferred to the fluid (Figure 12).

SOLAR RADIATION

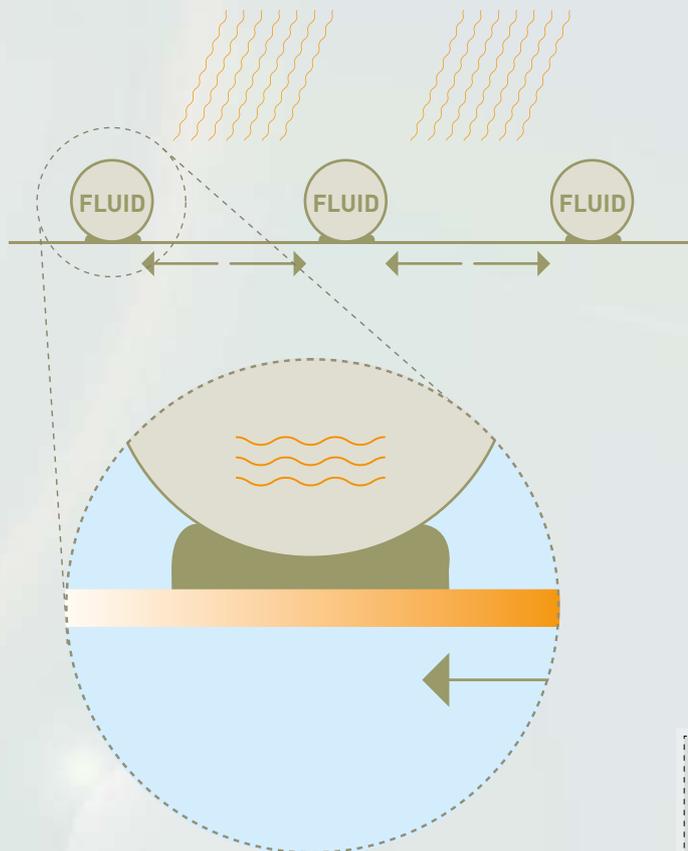
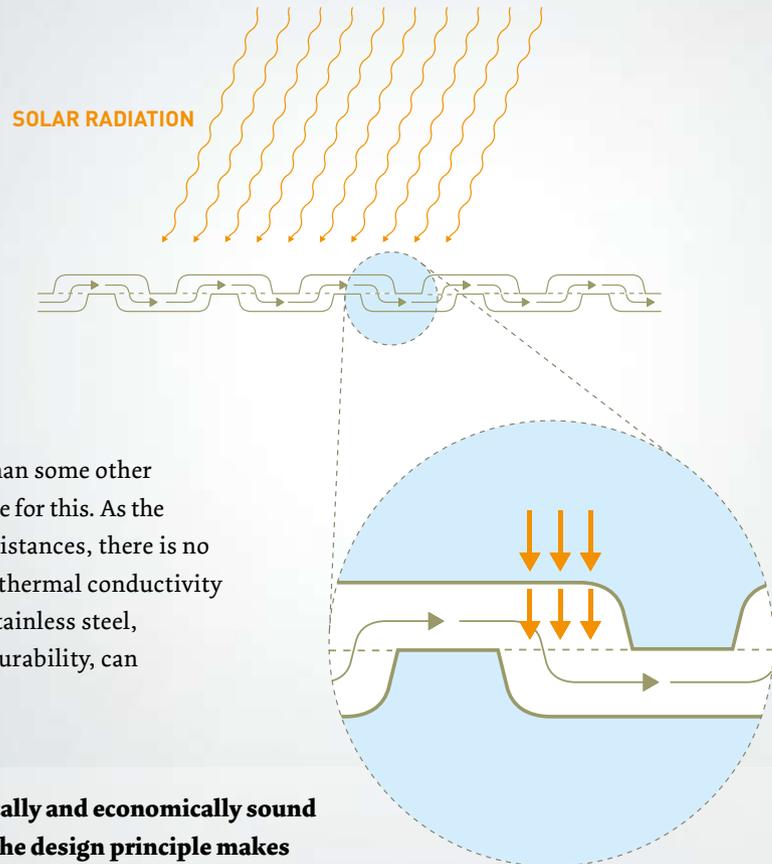


FIGURE 12: Principle of thermal energy transfer in conventional glazed panels. The thermal energy needs to be conducted over longer distances until it can be transferred to the fluid. Therefore, expensive materials with particularly high thermal conductivity are required to limit thermal losses.

Stainless steel absorbers work by transferring the thermal energy more directly to the fluid. Only 0.6 mm separates the incoming solar radiation from the fluid of the primary circuit. The heat only needs to penetrate the thin stainless steel sheet (Figure 13). The panels are mechanically resistant and designed to be used in pressurised systems. Visually, they are similar to conventional collectors (Figure 14).

FIGURE 13: Principle of the thermal energy transfer in stainless steel cushion panels. The thermal energy is transferred by the stainless steel directly to the fluid, making this design cost-effective.



Stainless steel has a lower thermal conductivity than some other metals. However, a specific design can compensate for this. As the energy does not need to be conducted over long distances, there is no need for more expensive materials with elevated thermal conductivity (Figure 13). The intrinsic material properties of stainless steel, excellent corrosion resistance and outstanding durability, can be fully used.

Stainless steel cushion-absorbers are a technically and economically sound solution for glazed absorbers (Figures 14,15). The design principle makes the relatively low thermal conductivity of stainless steel irrelevant.



FIGURE 14: Stainless steel cushion-absorbers are a technically and economically favourable option for glazed solar-thermal panels (Photo: energie-solaire.com)



FIGURE 15: Glazed panels are most efficient when oriented towards the midday sun (Photo: energie-solaire.com)

Stainless steel frames for solar-thermal panels

Whatever material is used to make the solar-thermal panels, they need a resistant frame. Stainless steel is again the preferred option. Stainless steel frames withstand the robust conditions on a building site. Although stainless steel has a higher density than other metals, it also has much higher mechanical strength. Therefore, the wall thickness of stainless steel frames can often be reduced to a point where they are of a similar weight to “light metal” options (Figure 16).

Because of their unique mechanical properties, stainless steel frames can be quite thin. This is useful from an architectural point of view. The stainless steel frames also resist high wind and snow loads – an advantage in parts of the world where the panels are exposed to these elements.

Stainless steel is selected for use in solar panels primarily because of its superior corrosion resistance. So-called light metals, although they are often considered to be corrosion resistant, can in fact suffer corrosion. However, as the corrosion products are white, they are less visible. Stainless steel is corrosion-resistant through and through. Even if the material is damaged, its intrinsic self-healing capability ensures that the surface does not discolour or corrode. This unique property is called passivation.¹ It is the reason why stainless steel does not need any coatings or other forms of surface protection to remain bright and shiny.

Because of their high mechanical properties, stainless steel sections for frames can be much thinner than their conventional counterparts. The fabricated frame can be as light as other “light metal” solutions.

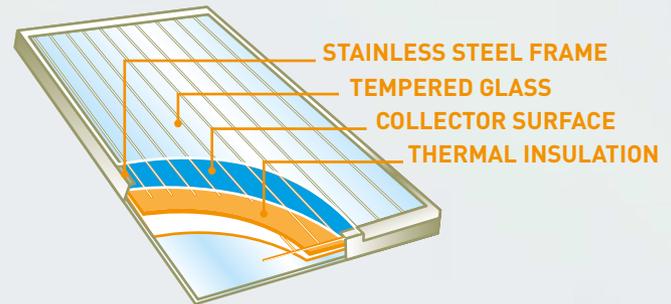


FIGURE 16: Stainless steel sections can be as light as their light metal counterparts

¹ The video *Stainless Steel – Self-Protecting for Lasting Value* provides an easy-to-understand and entertaining explanation of passivation in stainless steel. It can be viewed on the ISSF website worldstainless.org.

Unglazed stainless steel roofing panels

Why put solar panels onto the building envelope if the solar panel can be the building envelope? Over 20 years ago, designers developed a system which integrates both functions. On one hand it is an architecturally-attractive roofing panel, on the other hand it is a solar collector.

The system uses a cushion-type panel. The panel consists of two 0.6 mm stainless steel sheets which are formed into a wafer-like structure (Figure 17). The two sheets are assembled back to back, with the peaks and troughs shifted against each other so the fluid can flow through the resulting voids. Both sheets are spot-welded between the square bumps and seam welded at the periphery. This configuration ensures a uniformly spread water flow in the panel (Figure 18).

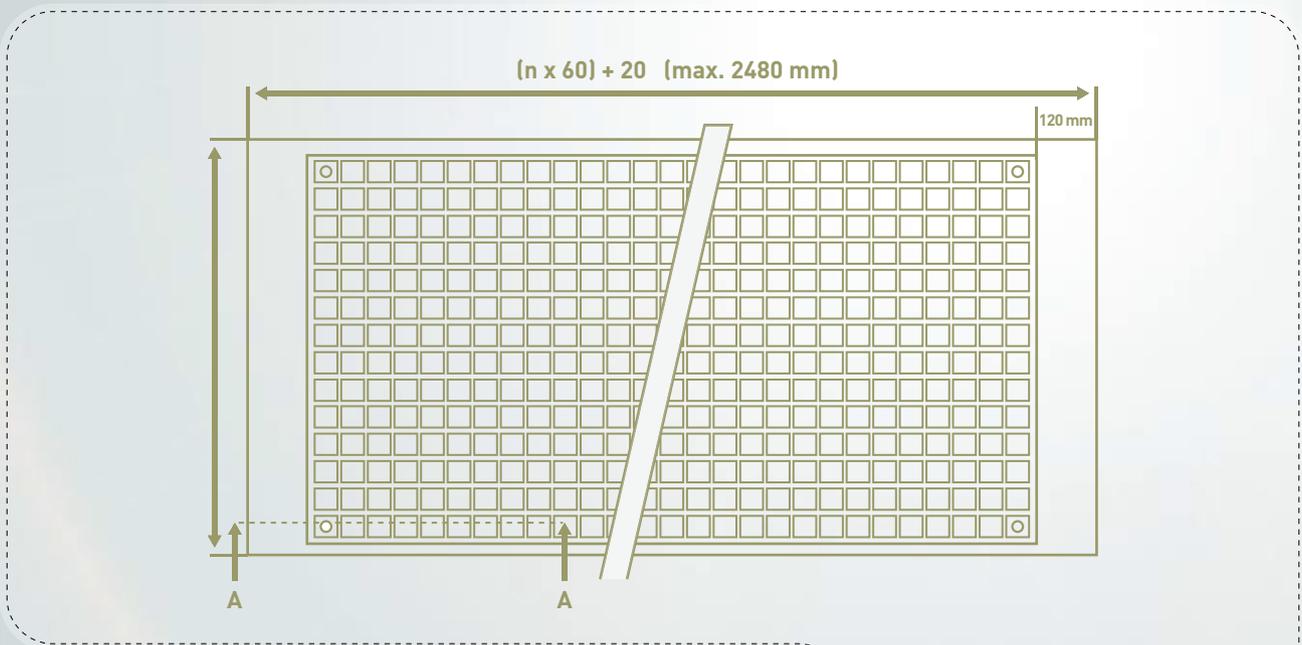


FIGURE 17: Wafer-type stainless steel sheets

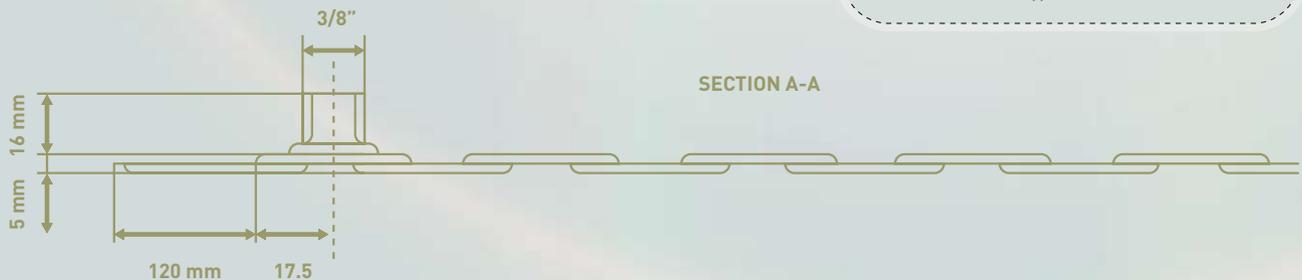


FIGURE 18: Assembly of two sheets, spot-welded against one another, to form a cushion absorber

The outer surface is chromed black. This functional layer is reminiscent of classic roofing materials like slate or roofing tile. It upgrades the panelling into an architectural feature. The reflectivity of the panel is low, making it perfectly compatible with any built environment (Figure 19).

Collectors can lose heat at night if they are not glazed. If yield per square metre is the only consideration, unglazed collectors may have a lower overall efficiency than glazed ones. However, as the collectors can fully replace conventional roofing panels (Figure 20) in the building envelope, more generous surfaces are available to make up for this effect.



FIGURE 20: The absorbers can fully replace conventional roofing sheet
(Photo: energie-solaire.com)

In glazed systems, the overall efficiency of a panel is largely dependent on its orientation. In unglazed systems, the effects of slope and orientation are reduced. An inclined position facing the midday sun is not essential. Diffuse radiation is also absorbed well. For these reasons, unglazed stainless steel panels can also be used on vertical surfaces, even covering complete facades (Figure 21).

Unglazed panels can also be used to generate process heat (Figure 22) or to heat swimming pools. Laboratory tests, together with more than 20 years of practical experience, prove the durability of the stainless steel solution.

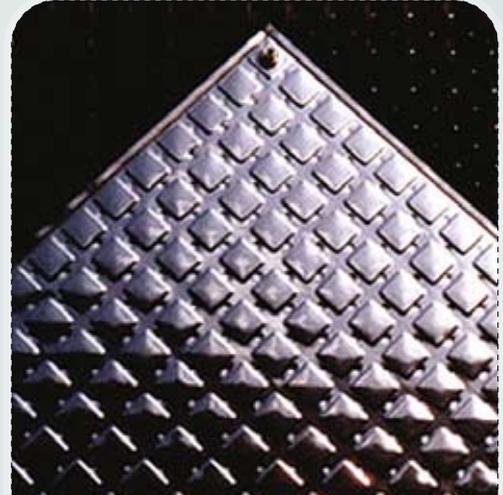


FIGURE 19: The black-chromed surface is efficient as a thermal energy absorber. It blends well with any architectural environment. (Photo: energie-solaire.com)



FIGURE 21: The black-chromed surface is efficient as a thermal energy absorber. It blends well with any architectural environment. (Photo: energie-solaire.com)



FIGURE 22: Stainless steel panels used to generate process heat in an aromatic-herb drying plant on Mallorca Island, Spain (Photo: energie-solaire.com)



FIGURE 23: Organically-coated stainless steel solar roofing panel (Photo: plou i fa sol, copidees@coac.net)

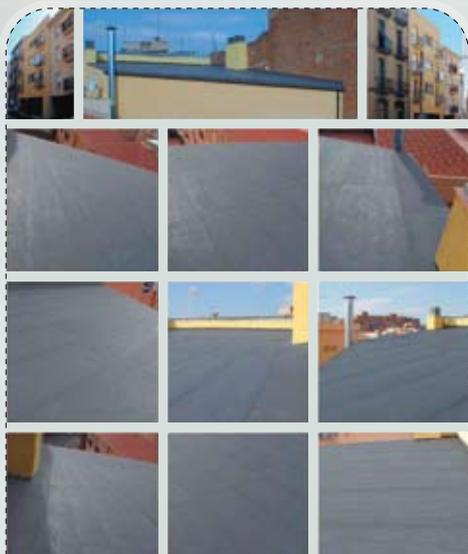


FIGURE 24: Solar panels of an apartment building at Reus, Tarragona (Spain); Photo: plou i fa sol, copidees@coac.net

Electrolytically-coated unglazed stainless steel panels use diffuse radiation and sunshine from different angles efficiently. The subdued gloss of the blackened metallic surface makes the cushion panels an elegant architectural feature for both roofs and facades.

Organically-coated unglazed stainless steel panels

Organically-coated sheet metal is also used in the production of solar panels. Stainless steel is an ideal substrate. Even if the coating gets damaged, for example, during erection, the supporting material does not corrode. Cushion type collectors are used (Figure 23).

The straightforward design provides an economically-priced solution. Ferritic stainless steel (an iron-chromium alloy) has also been used successfully². The use of solar energy is by no means limited to high-class prestige buildings. In apartment buildings the use of solar energy also makes sense. Some countries or local authorities now make the use of solar energy compulsory in particular types of buildings such as new apartment blocks which exceed a specific size. Social housing is no exception. Especially in warm climates, where sunlight is available in abundance, the panels have potential for volume applications (Figure 24).

The sandwich panel is also particularly light in weight. It can be fastened to light steel structures, providing an inclined roof at low cost (Figure 25).

² More information on this family of stainless steels is available in the brochure *The Ferritic Solution*, which can be downloaded from the ISSF website worldstainless.org

Coated ferritic stainless steel is an economically-priced solution, which combines roof skin and solar panel into a single building component.

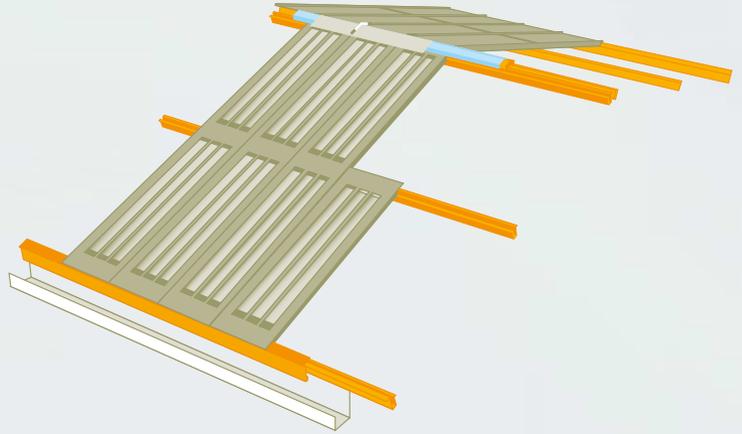


FIGURE 25: Solar panels fastened to a light steel roofing structure

Connectors

Irrespective of the material used in the panels, the connectors are often made from stainless steel. The ultra-thin stainless steel can be formed into a bellows-like structure (Figure 26) and easily bent. The connectors do not age under the influence of ultraviolet radiation and are corrosion resistant in the most diverse atmospheric conditions.



FIGURE 26: Stainless steel tubes and connectors do not age and are corrosion resistant. (euro-inox.org/witzenmann.com)

Photovoltaic cells

Photovoltaic (PV) cells turn sunlight into electricity. Numerous technologies are available to create PV cells. One solution uses wafer-like cells, which consist of silicon similar to that used in the fabrication of computer chips. A lack of production capacity for these cells has been a bottleneck in the development of the technology for many years. Today, alternatives like amorphous cells are available, giving the user a range of technical options.

Flexible PV modules on stainless steel roofs

The integration of solar devices is an important consideration in building design. The building envelope (including roofs and façades) exists anyway. Multifunctional building elements, such as thermal collectors and PV modules, can turn a roof or façade into a thermal or electric power plant.

Flat roofs

Flexible PV cells (for example, triple cells of amorphous silicon, Figure 27) can be applied on metal sheets covering a roof. Stainless steel roofing is especially suitable because there is no limitation to either the tilt angle of the roof or its tightness.

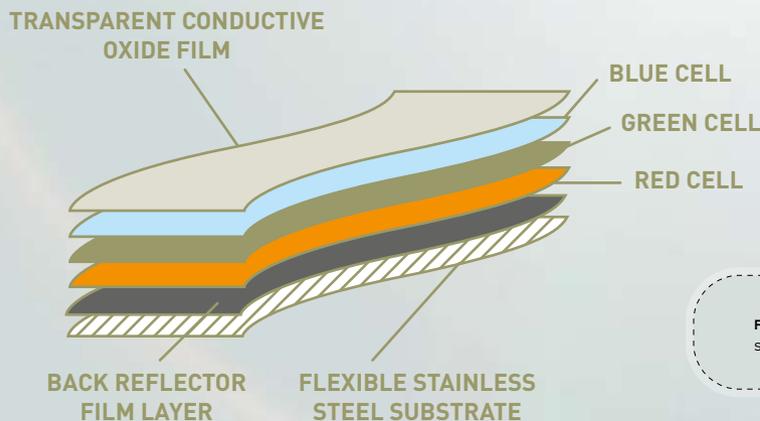


FIGURE 27: Cross-section of triple-junction amorphous silicon-alloy solar cell (Photo: adapted from uni-solar.com)

PV cells exhibit optimum performance when they are oriented towards the sun (to the south in the northern hemisphere and to the north in the southern hemisphere) and have a tilt corresponding to the geographical latitude. Crystalline-silicon modules are sensitive to deviations from this ideal situation. However, thin-film modules (such as amorphous silicon) are much less sensitive to orientation. This makes it possible to integrate the modules into roofs, even flat roofs (Figure 28),

without losing too much energy efficiency. The efficiency of amorphous silicon PV cells is approximately 6%. This means that about 15 m² of modules generate 1.0 kW of electric power in sunshine. The flexible modules are laminated on the stainless steel roofing elements (Figures 29-30). As they are waterproof, the electrical connection can be realised through holes in the roofing elements which are covered by the photovoltaic modules. The roof is tightened and finished in one operation. The connections and installation of the electric system are made later from inside the building.



FIGURE 28: Flat stainless steel roof with integrated amorphous PV cells (Photo: uni-solar.com)



FIGURE 28: Flat stainless steel roof with integrated amorphous PV cells (Photo: uni-solar.com)

FIGURE 30: Commercial building with a near-flat roof completely covered with multifunctional stainless steel PV units. The electrical output power is about 150 kWh. The annual electrical output in a sunny climate can be up to 300,000 kWh/year. (Photo: uni-solar.com)



Amorphous photovoltaic cells go together ideally with stainless steel roofs

Tilted roofs



FIGURE 31: The stainless steel tilted roof of a museum building with integrated photovoltaic modules
[Photo: thyssen-solartec.com]

The combination of different functions in one unit is a proven method of economical building construction. It is also an important feature of architectural design. Solar energy devices may be added as boxes to roofs or façades. However, a better and more efficient method is the integration of these elements into roofs and façades as multifunctional compound units (Figure 31).

Flexible PV cells (for example, triple cells of amorphous silicon) are applied on metal sheets covering a roof (Figure 32). Stainless steel roofing is especially suitable because there is no limit to the tilt angle of the roof or its tightness.

Multifunctional stainless steel PV compound units may be single-leaf or sandwich elements. In both cases the outer side is laminated, either partly or completely, with flexible photovoltaic modules. The cable entry to the inner side is covered by the module (Figure 32). Weather protection and PV energy gain can be integrated into the roof in a very simple way using these modules. It is also possible to make the entire roof PV active, or to combine active sections with non-active ones.

The advantage of building with integrated PV modules is that the basic compound system can be applied in the usual way. This includes all constructive conditions and connections to other parts of the building. The roof can be finished before the completion of the electrical system inside the building.



FIGURE 32: Detailed view of a tilted stainless steel roof. Active PV sections can easily be combined with non-active ones.
[Photo: thyssen-solartec.com]



FIGURE 33: Assembly of stainless steel sandwich roofing elements with integrated amorphous PV modules.
[Photo: thyssen-solartec.com]

The possibility of integrating amorphous silicon PV modules into pitched roof compound units is almost independent of their detailed construction. Elements with a vertical orientation (Figure 34) can also be made multifunctional PV compound units with all the advantages mentioned above.

Stainless steel is a proven metallic substrate for amorphous photovoltaic cells. The flexible cells can be used on a wide variety of supports.



FIGURE 34: Pitched stainless steel roof with integrated amorphous silicon PV modules and non-active parts (Photo: uni-solar.com).

Architectural integration of crystalline PV modules

The architectural integration of solar technology is often a point of concern. Ideally, solar panels should be considered as part of the architectural expression and a means of providing a visual structure to roofs and facades. In an effort to bring the best technologies together, stainless steel roofing solutions have been developed which precisely match photovoltaic panels (Figure 35).



FIGURE 35: The trays of the stainless steel roof support the photovoltaic panels (Photo: protectum.de)



FIGURE 36: In flat parts of the roof, where rainwater does not flow off easily, the stainless steel welded seam option is the only possible metallic solution. (Photo: protectum.de)

One solution involves making the solar panels and the metallic trays of the roof the same width. The panels are fully sunk into the voids, creating a uniform and aesthetically-pleasing roofing skin.

The joints can be seam-welded to produce a permanently watertight roof. Often, type 304 and 316L stainless steels are selected for this purpose. Higher-alloyed ferritic grades have also successfully been used. This roofing technology is the only metallic option that can be used on zero-degree roofs or non-inclined parts (Figure 36).

The roofing materials should match the durability of the solar panels. General corrosion is virtually absent in stainless steel. As a result there are no obvious limits to the durability of the roof. Typically, the useful life of a stainless steel roof is only restricted by the service-life of the building as a whole. Stainless steel is certainly a good investment both in durability and aesthetics on any type of building including private homes (Figure 37).



FIGURE 37: Integrated stainless steel and solar technology systems can be applied to buildings of any type and size. (Photo: protectum.de)

Stainless steel roofing is an excellent support for PV cells, providing architectural integration of roof skin and panels.

Fasteners

Whatever type of solar energy is used – it typically involves panels. The panels need to be fastened securely, usually to a roof (Figure 38). The mechanical properties and corrosion resistance of the fasteners are critically important for the safety of the installation.

Stainless steel is among the most reliable options for this application. Once installed, the panels often hide the fasteners and make them inaccessible for further inspection. In the hidden areas, the accumulation of dirt or pollutants is difficult to control. For this reason, a corrosion-resistant material, such as stainless steel, is needed. The fasteners must have at least the same durability as the PV cells (that is, several decades) without losing their reliability.



FIGURE 38: PV panels fastened to stainless steel sections (Photo: modersohn.de)

In many parts of the world, the occurrence of extreme weather conditions like storms, torrential rainfall or blizzards has increased. The fasteners must also resist these extreme conditions. Some countries are adapting their building codes accordingly by increasing the requirements on fasteners and solar panels.



FIGURE 39: Stainless steel fasteners for solar panels (Photo: solar-gmbh.de)



FIGURE 40: Duplex stainless steel (23% chromium/4% nickel) is a cost-effective option for safety-critical parts (Photo: modersohn.de)

Classic grades like 304 and 316 have been used for fasteners. However, some of the lower-alloyed duplex stainless steels (containing about 23% chromium and 4% nickel) have made inroads into this application recently (Figures 39 and 40). There are many reasons for this change. Compared with usual austenitic grades, duplex grades have considerably higher mechanical resistance, even in welded fabrications. Wall thickness can often be reduced, leading to lighter and visually unobtrusive designs. Because of their alloying composition, duplex grades are often particularly cost-effective. Technically, their resistance against pitting and crevice corrosions is similar to, or even higher than, that of reference grades like 304 and 316. Lower thermal expansion facilitates the design.

The mechanical properties of stainless steel make the material ideal for fasteners. Some duplex grades, which have a mixed ferritic and austenitic structure, provide a particularly interesting combination of reasonable cost and high mechanical strength.

Stainless steel the sustainable option

There are many approaches to producing electricity and domestic hot water from solar energy. Whatever the technology, stainless steel has a role to play. It can be used as part of a substrate of amorphous cells or as a collector material in solar thermal panels. It can be found in ancillary components such as frames, fasteners and connectors. Stainless steel can also be an essential element in downstream equipment such as tanks and heat exchangers. Wherever it is used, stainless steel makes a contribution to the sustainability and eco-friendliness of our built environment.
