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SOLAR ENERGY SYSTEMS IN ARCHITECTURE

integration criteria and guidelines

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CONTENTS

4. PHOTOVOLTAICS VS SOLAR THERMAL: VERY DIFFERENT BUILDING INTEGRATION POSSIBILITIES ANDCONSTRAINTS

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4.1. INTRODUCTION

The ever increasing interest for renewable energies results in a constantly growing market demand for active solar systems, both for electricity (photovoltaics) and for heat production (solar thermal).

This trend, added to the new promotion policies recently set up by the EU, let foresee an increased interest for all the sun exposed building surfaces, resulting in a new debate on how to optimize their use for the production of solar electricity and/or solar heat.

Although similarities in the integration on the building envelope of solar thermal and photovoltaic systems do exist, there are also major differences that need to be considered. Both technologies deal with the same building skin frame, and have similar surfaces and orientations needs. On the other hand they have different intrinsic formal characteristics, different energy transportation and storage issues, different insulation needs, shadow influence, etc...

The impact these technology peculiarities have on the building implementation possibilities are described here to support making the best use of the available exposed building surfaces.

4.2. COMPLEMENTARITY ELEMENTS

Solar thermal and photovoltaics are complementary and equally crucial technologies to minimize a building fossil fuel energies consumption and related CO_2 gas emissions: PV is needed to produce the electricity for appliances and artificial lighting, solar thermal is needed to provide heat for DHW and can be used for space heating (in the near future also for cooling) (Tab.1) (see also ch.1-Introduction, page3).

BUILDING ENERGY NEEDS	CORRESPONDING SOLAR TECHNOLOGIES	
	PASSIVE	**ACTIVE**
SPACE HEATING	PASSIVE SOLAR	SOLAR THERMAL
DOMESTIC HOT WATER	-	SOLAR THERMAL
ELECTRIC APPLIANCES	-	PHOTOVOLTAICS
LIGHT	DAYLIGHTING	PHOTOVOLTAICS
(SPACE COOLING)	(FREE COOLING)	(SOLAR THERMAL / PV)

Fig 4.1: Building energy needs and corresponding solar technologies

As both PV modules and solar thermal collectors produce energy from the sun and need to be placed on the sun exposed areas of the building skin, the issues related to their integration in the building envelope are often treated together, assuming they are part of a unique problematic. This simplification may be acceptable for very small solar systems and where the needed surfaces are much smaller than the exposed areas actually available. But in most cases, to optimize the use of the available - finite- exposed surfaces; the specificities of each technology should be taken into account, especially in buildings with high solar fractions.

Photovoltaics and solar thermal are fundamentally different, as one is designed to transform the solar radiation into electricity, and the other is designed to transform it into heat: two different energies, with very different transportation and storage issues. This brings different formal and operating constraints, leading to different building integration possibilities.

To help architects implement both types of systems while using optimally the sun exposed surfaces of their buildings, we will analyse the ways the characteristics of these two technologies affect building integration (see ch.2 Architectural integration quality, page 6).

4.3. SIGNIFICANT COLLECTORS FORMAL CHARACTERISTICS

Both fields of solar thermal and PV count several technologies interesting for building integration: monocrystalline, polycrystalline and thin films in the field of PV; glazed flat plates, unglazed flat plates and vacuum tubes collectors in the field of solar thermal. Unless differently specified, the following considerations refer to the most diffused ones in EU, i.e. crystalline -mono and poly- cells for PV and glazed flat plate collectors for solar thermal.

To keep the message clear and short, distinctions will be made only when considered important.

For a detailed description of Solar Thermal an Photovoltaic technologies please refer respectively to ch.3-A and ch. 3 B of the present document.

4.3.1 Shape, size, flexibility

The basics shape, size and dimensional flexibility of the PV modules are fundamentally different from the ones of thermal collectors.

The size and shape of PV modules are very flexible since they result mainly from the juxtaposition of single squared silicon cells (mono or polycrystalline) of approximately 12 to 15cm side. Modules can come in the size of less then 0.1m^2 (few cells) up to 2m^2 (more than 60 cells). Thanks to the flexibility of the internal connexions and the small cells' size, made to measure module can be provided in almost any shape (at a higher price in this case). Moreover the possibility of partial transparency is offered through glass-glass modules. Thin films modules can also offer a new level of freedom when using flexible metal or plastic sheets.

Solar thermal collectors are much bigger (1.5 to 3m^2) and their shape definitely less flexible. This derives mainly from the need of a non flexible hydraulic circuit fixed to the solar absorber to collect the heat: the freedom in module shape and size would require reconsidering every time the hydraulic system pattern, which is generally difficult and expensive. The lack of market demand for architectural integration is also a cause of this poor offer up to recently. The case of evacuated tubes is different: the panel size and shape result from the addition of evacuated tubes: length from 1 to 2m, diameter from 6 to 10cm. In most cases though, only standard modules are available.

Impact on building integration

Ideally, the shape and size of the solar module should be compatible with the building composition grid and with the various dimensions of the other envelope elements. The lack of flexibility associated to the large size of solar thermal collectors reduces significantly the possibilities of proper implementation. The higher shape and size flexibility of photovoltaics modules and their small size make it easier to deal with both new and pre-existing buildings. These different flexibilities imply very different constraints when choosing the shape and placement of the collectors' field(s), especially for façade integration.

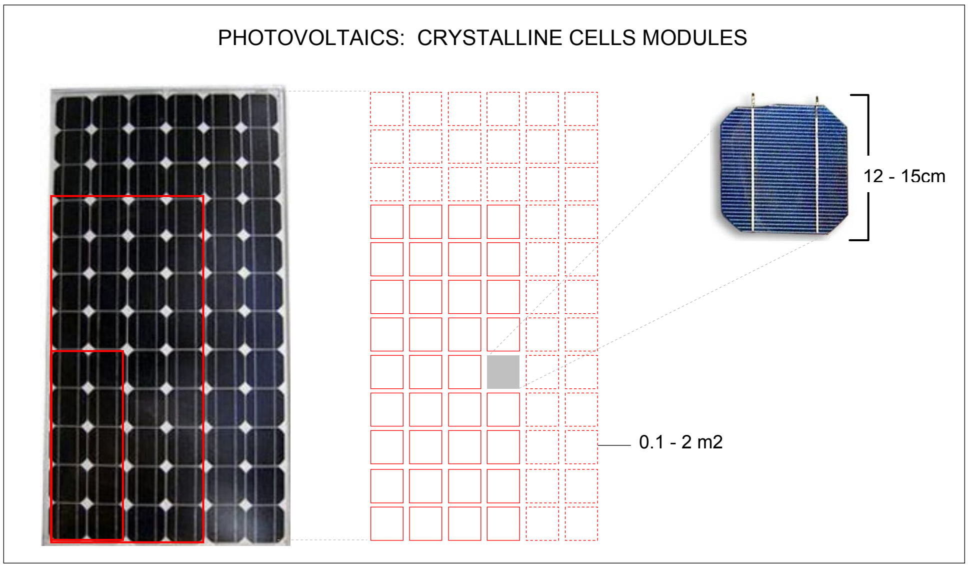


Fig. 4.2: shape and size flexibility of crystalline photovoltaic modules

Fig. 4.3: typical low flexibility in size of standard glazed flat plates collectors

4.3.2 Module structure, thickness, weight

The thickness and weight of PV and solar thermal modules are also totally different. PV modules are thin (0.4 to 1cm) and relatively light (9-18 kg/m^2), while solar thermal ones are much thicker (4 to 10 cm) and heavier (around 20 kg/m^2).

PV mainly consists in thin laminated modules encapsulating the very thin silicon cells layer between an extra white glass sheet (on top) and a composite material (Tedlar / Mylar) or a second sheet of glass.

Solar thermal collectors are composed by multiple layers in a sandwich structure: glass sheet / air cavity / metal absorber / hydraulic system / insulation. Evacuated tubes have a different structure: an absorber core protected and insulated by a glass tube.

<u>*Impact on building integration*</u>

The difference of weight between the two types of modules presents mainly different characteristics in handling (1 person vs. 2 persons for the mounting), but does not have a relevant impact on the under construction structure.

The thickness on the contrary does affect the integration possibilities, especially in facades. While the thinner PV modules can be used as sun shading on facades, and easily implemented as a cladding, the thickness of solar thermal makes the sun shading application problematic and the use as cladding more delicate, especially in retrofits. This is also true, on a lesser degree, for the roof applications.

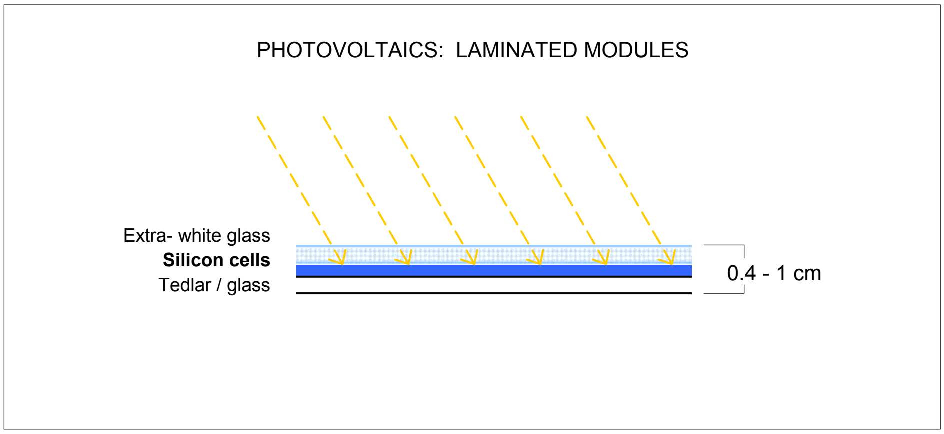


Fig 4.4: Low thickness characterizing of photovoltaic modules

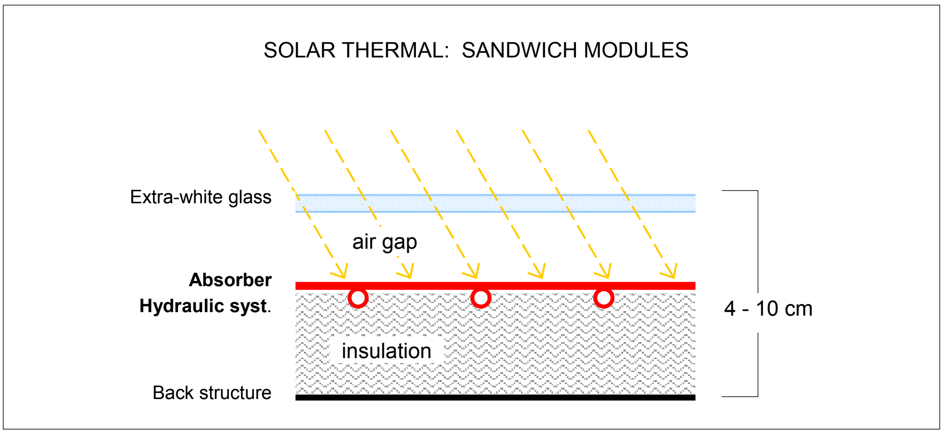


Fig 4.5: Thickness of standard glazed flat plate collectors

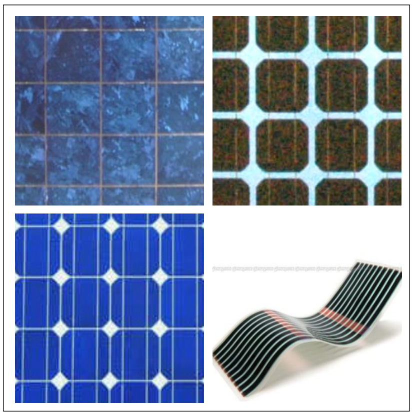
4.3.3 Visible materials / surface textures / colours

The external layer of both PV and solar thermal modules consists in a sheet of extra white glass. The glass surface can be smooth, textured or acid etched, but always lets see the internal layer: the silicon cells in PV, the metal absorber in solar thermal.

The structure, the geometry and the appearance of these layers are very different: the metal absorber of solar thermal collectors is generally continuous and covers the whole module area, while for PV the cells can be arranged in different patterns, also playing with their spacing.

PV crystalline cells have a flat surface, mainly blue or black, with a squarish shape. The absorbers of thermal collectors are characterized by a more or less corrugated metallic surface, coated in black or dark blue.

Evacuated tubes are different, as described in section 3.2 of the present chapter.



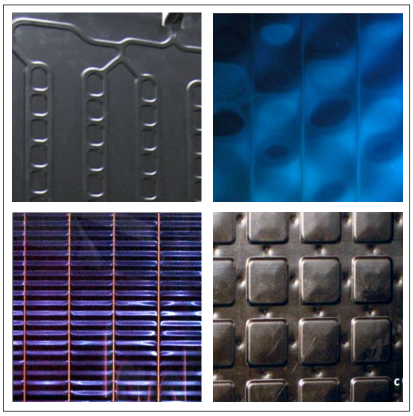


Fig 4.6 and 4.7: Visible surface colours and textures of PV modules (left) and ST collectors (right)

<u>*Impact on building integration*</u>

Due to the above described characteristics of their absorbers, flat plate thermal collectors can be implemented only on opaque areas of the building envelope (roof or facades), while PV modules can be mounted also on transparent ones. When mounted in a glass/glass module, the cells can be freely spaced with a resulting variable module transparency, well adapted for atrium / veranda/ sheds or glazed facades applications.

The structure of evacuated tubes could allow the mounting on the transparent envelope areas, as sun shading for instance. This type of application is very rare though, due to the lack of products developed for this specific use.

4.4. ENERGY TRANSPORT AND STORAGE

As PV modules produce electricity and solar thermal produces heat, they have to deal with different energy transportation, storage and safety issues.

4.4.1 Energy medium and transport

Electricity can be transported easily and with very small losses through thin (0.8-1.5cm diameter), flexible electric cabling. It can then be easily transported over long distances, so that the energy production doesn't need to be close to the consumption place.

Heat is transported by water (charged with glycol to avoid winter freezing) through the rigid piping of the hydraulic system. Heat transportation is very sensitive to losses, meaning on one hand that the piping system has to be very well insulated (resulting diameter: 3 to 8cm), on the other hand that the heat should be used near the production place.

Impact on building integration

Compared to the small size and flexibility of electrical cables, the rigidity, size and need for insulation of solar thermal piping requires much more space (and planning care) to be accommodated in the building envelope.

The different types of energy transport bring also different building safety measures: preventing water leakage damages for solar thermal, preventing fire propagation for PV. Water pressure issues should also be considered when dimensioning the solar thermal system, in particular when defining the vertical field size. But the fundamental difference rising from the different transport issues is that while solar thermal needs to be installed close to the place where the heat is needed, PV can be installed anywhere, even very far from the consumption place. This should be taken into consideration when working on sensible urban areas, like historical city centres or protected buildings.

4.4.2 Energy storage

Because of the different ways these energies can be transported, their storage issues are radically different, affecting strongly the implementation possibilities.

The electricity produced by the PV modules can be injected practically without limits into the grid. As a result the sizing of the system is totally independent from the local consumption and the energy produced can exceed by far the building electricity needs.

On the contrary, the heat produced by thermal collectors has to be stored close to the consumption place, usually in the building storage tank. In practice, the storage capacity of the water tank is limited, usually offering no more than a few days autonomy. Furthermore, solar thermal collectors are sensitive to damages resulting from overheating, so that ideally the heat production should not exceed the storage capacity.

Impact on building integration

The sizing principles of the two types of systems are completely different: Solar thermal systems should be dimensioned according to the specific building needs and to the storage tank capacity, to avoid overproduction and the accompanying overheating problems.

PV is totally independent from the building energy needs and can be dimensioned just according to the size of available exposed areas, or according to architectural criteria for instance.

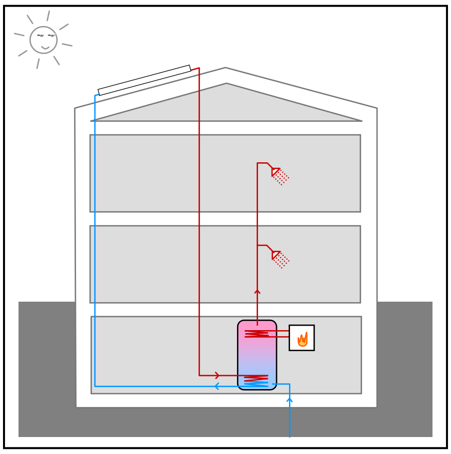


Fig. 4.8 (left): Public grid for electricity transport and storage

Fig. 4.9: Tipical hot water storage system in insulated tank placed in the building itself (limited storage volume).

4.5. OPERATING CONSTRAINTS

4.5.1 Operating temperatures and related insulation needs

Suitable operating temperatures are again different between the two technologies: for PV, especially for crystalline cells, the lower the operating temperature, the better; for solar thermal, the higher the better (still avoiding overheating).

Impact on building integration

This difference affects once more the integration possibilities in the building envelope: PV modules should be back ventilated for a higher efficiency; solar thermal absorbers require back insulation to minimize heat losses. Integrating the collectors directly in the building envelope layers, possibly without air gap, is ideal in this sense for solar thermal, while freestanding or ventilated applications would be preferable for PV.

4.5.2 Shadows

Impact on building integration

For solar thermal, the heat losses resulting from partial shadowing are just proportional to the shadow size and don't cause any particular production or safety problem. Photovoltaics on the other hand can be very sensitive to partial shadowing: the electricity production may be greatly affected by partial shadows if special care is not given to the modules placement and string cabling. The energy losses are generally higher than the shadow ratio, with possible risks of modules damage if its impact is not well considered during the system design phase.

4.6. CONCLUSIONS

As shown above, there are clear differences in the characteristics of solar thermal and photovoltaics systems, leading to different approaches when integrating them in the building envelope. A synthetic overview is presented in the table below (fig. 4.11).

Fig. 4.9 (left) and 4.10 (right): photovoltaic products (left) and solar thermal products on the market.

Several considerations can be derived from these observations, which cannot all be presented here.

		PHOTOVOLTAICS *	SOLAR THERMAL**
FORMAL CHARACTERISTICS	MODULE SIZE	0.1 to $2m^2$	1.5 to $3m^2$
	SHAPE / SIZE FLEXIBILITY	High flexibility	Low flexibility
	THICKNESS	0.4 cm to 1 cm	4 to 10 cm
	WEIGHT	9-18 kg/m^2	20kg/m^2
	MODULE STRUCTURE	laminated modules	sandwich modules
	MATERIALS	Glass / silicon cells / Tedlar -Mylar or glass	Glass / air / metal absorber / hydr.system / insulation
	SURFACE TEXTURES	External glass: smooth / acid etched / structured. Silicon cells: variable patterns, possible transparency	External glass: smooth / acid etched / structured. Absorber: slightly corrugated, opaque metal sheet
	COLOURS	Black / blue mainly.	Black / dark blue mainly
TECH. CHARACTERISTICS	ENERGY MEDIUM	Electricity	Hot water
	ENERGY TRANSPORT	Flexible cabling (0.8-1.5 cm diameter). Low energy losses.	Rigid insulated piping system (3-8 cm diameter). High energy losses.
	ENERGY STORAGE	Presently unlimited, into the grid	Limited to building needs / storage capacity of the building tank.
	WORKING TEMP.	The lower the better (back VENTILATION required)	The higher the better (back INSULATION required)
	SHADOWS IMPACT	Reduction in performances higher than shadow ratio; risks of permanent damage to the panel.	Reduction of performances proportional to shadow size, no damage to the panel.
	ENERGY PRODUCTION	80- 120 kWh/m^2 per year	450-650 kWh/m^2 per year
	COST (CH – 2009)	300.- to 450.- €/m^2	300.- to 450.- €/m^2

* valid for crystalline cells

**valid for glazed flat plate collectors

Fig 4.11: Formal and technical characteristics of Photovoltaics and Solar Thermal. (Please remember that the two technologies are not interchangeable, hence are not competing against each other: both are equally needed as they cover different building needs)

It is important to underline one major outcome that concerns the positioning options induced by the different storage constraints:

As there are presently no limitations in the storage of the energy produced by PV, its annual energy production should be optimized by locating and orienting the PV where its sun exposure is maximized (tilted or flat roofs mounting in most cases) (cfr. 4.4, and ch.3.B p.59-62).

This brings one interesting option for solar thermal integration. In EU mid latitudes, where the solar radiation varies dramatically during the year, the maximum summer production can be twice the winter one. To avoid summer overheating, tilted solar thermal systems are usually undersized (solar fractions around 50%). A good way to increase the whole year solar fraction while limiting overheating risks is to mount the collectors vertically, using the facade areas. The heat production would then be almost constant during the year, making it possible to dimension the system according to the real needs (Fig.1). This allows solar fraction of up to 90%, while opening the way to building facades use (ref. ch.3A.2, page18).

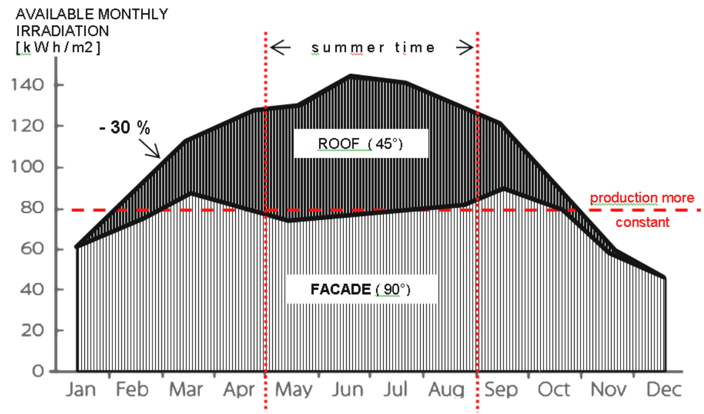


Fig. 4.12: Comparison of the monthly sun radiation available on a 45° south oriented tilted surface vs. a vertical south oriented surface in Graz, Austria (47°latitude). Data from W.Weiss, I.Bergmann, AEE-Intec.

However, if for photovoltaics there is a large offer of products suitable/conceived for building integration, exploiting the flexibility of the technology, the situation is different for solar thermal. The big size of most collectors now available, their lack of dimensional flexibility as well as the dark irregular appearance of their absorber makes it difficult to integrate solar thermal, particularly on facades. This is an issue that should be solved urgently, especially in the light of the previous considerations:

New solar thermal products conceived for building integration should be developed, matching the offer available in the PV field, to help answer to the booming demand for architectural integration of solar in buildings.

This is even more important considering the high efficiency and cost effectiveness of this technology.

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