A NEW GENERATION OF HYBRID SOLAR COLLECTORS

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ABSTRACT: A new generation of hybrid solar collectors (electricity, heat) is being developed. The results of the feasibility study are encouraging since they show:

- that a potential **market** exists for the described applications (about 11 MW in 2005)
- that the **photovoltaic (PV) thin film** technology is likely to be suited for this application from a technical and a financial point of view, provided the long term stability of the cells at temperatures above 100°C are confirmed
- that several **photovoltaic industries** are ready to collaborate in their development (with different participation degrees)
- that **technology packages** are suited for the hybrid collector.

These results also show that the competitiveness of the hybrid collector presupposes that:

1) the **absorption coefficient** of the photovoltaic absorber (we call photovoltaic absorber the photovoltaic device which replaces the absorber of the conventional thermal collector) is greater than 80% instead 72% for present modules.
2) the **long term stability** of the PV-cells is tested at temperatures between 100 and 170°C
3) the final cost of the **direct bonding** (i.e. the lamination of the photovoltaic device with the thermal exchanger) does not exceed 35 Swiss Francs per m^2 (1 Swiss Franc ≅ 0.63 Euro ≅ 0.71 US $)
4) **labor costs** do not go up dramatically
5) **costs** and **efficiency** of thin film PV technologies evolve favorably.

The benefits of hybrid collectors are less sensitive to points 4 and 5 which in any case this project can influence. The information needed for a better understanding of points 1 to 3 (value of absorption in the whole solar spectrum, technical feasibility of standard and new encapsulation products and processes,...) is neither available in technical prospects or the scientific literature nor from the concerned companies with the closest know-how. For these reasons, the developers of the hybrid collector must carry out a series of measurements and technical experiments before going into product design.

Keywords: Hybrid – 1: Thermal performance – 2: Thin Film – 3

1. NEW GENERATION CONCEPT

The main obstacle to an earlier development of the hybrid module was not only the non-existing market but also the unfavorable temperature coefficient of crystalline cells. For this reason, we propose a new generation concept where thin film technology is used. The diagram of Fig. 1 shows that the relative loss of power remains smaller at a service temperature above 50°C.

One can consider the price of a Watt at service temperature (Fig. 2).

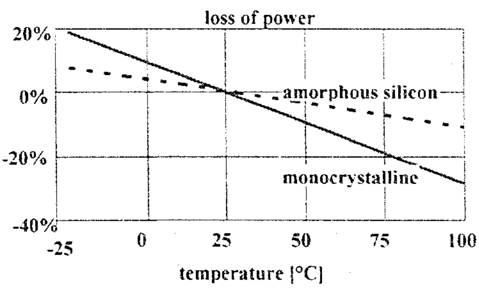

Fig. 1. Power loss in relation to the temperature

Assuming the same price at standard test conditions (1000W/m^2 and 25°C), an amorphous silicon (a-Si) photovoltaic module becomes 14% more cost-effective at 75°C and 24% at 100°C compared to a crystalline one. Another benefit lies in the reversing of the Staebler-Wronski effect. Since the future of photovoltaics probably belongs to thin films, we are convinced that the hybrid collector has to use the a-Si technology.

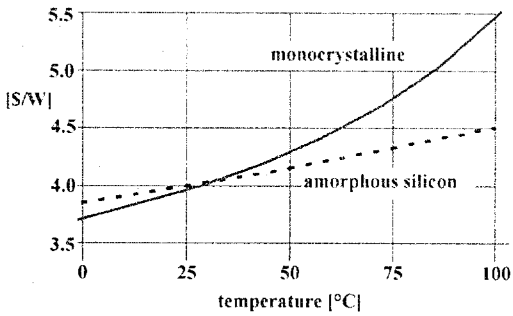

Fig. 2. Power cost in relation to the temperature

The new generation features another interesting improvement: the direct bonding of the PV device on the thermal exchanger. The construction process has to be neither more complicated (number of process steps), nor more expensive (type and quantity of materials) than for a standard PV module.
In addition to the use of thin film technology and direct encapsulation, other interesting features of the new generation are:

- Flat plate collector
- Fluid thermal exchange (higher thermal efficiency)
- Design allowing automated construction.

This concept must be implemented as simple as possible (no concentration with tracking system, no vacuum, ...) in order to make the development faster, the final product costs minimal and thus the market potential greater.

2. TECHNICAL AND ECONOMICAL ANALYSIS

Before starting the detailed development, it was important to check if the new generation of hybrid technology has chances to struggle against conventional technologies. A one-dimensional model was therefore implemented (Fig. 3). It allows calculating which thermal and electrical efficiencies can be obtained.

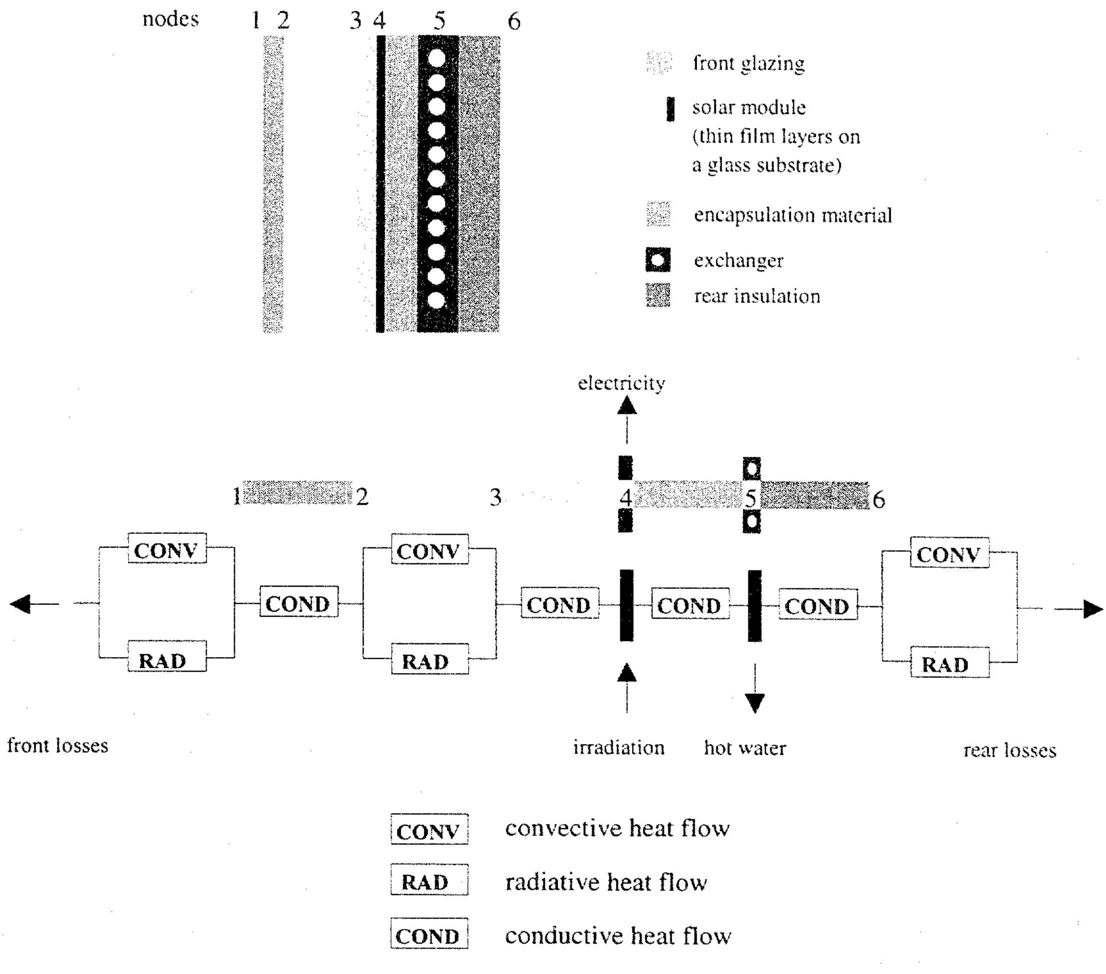

Fig. 3. One-dimensional model of the hybrid module

Based on the calculated efficiencies, a financial calculation was done in order to check the cost-effectiveness of the hybrid module compared to a conventional system. This method required several iterations in order to find out the technical and financial requirements. They are:

- Optical efficiency of the collector (Co value): ≥ 65% (that means the absorption of the PV module should reach at least 80%, instead of 72% for measured modules based on amorphous triple cells with steel substrate)

- Bonding cost of the PV module on the exchanger: ≤ 35 Swiss Francs per m^2 (similar to the cost of selective coating!)

- Savings on the mounting costs: ≥ 140 Swiss Francs per m^2

- Cost of the heat exchanger similar to the cost of a conventional uncoated solar absorber.

These are the requirements for a competitive hybrid collector. The absorption and the fin efficiency are technical objectives that seem feasible in the short term. The bonding and the mounting costs are now difficult to foresee since they strongly depend on the evolution of labor costs and on the further development of the hybrid collector.
The efficiency of the PV modules does not have a sensitive influence on the energy costs. It is the PV technology prices which have the most influence on the electricity cost (Laplace's evidence!). Nevertheless, this cost does not have much influence in the comparison between a mixed and a hybrid system.

3. TECHNOLOGY

The hybrid collector combines several technologies. Its structure can be divided in 3 main parts: the photovoltaic device, the thermal exchanger (which is not a solar absorber since the absorption is done on the photovoltaic layers!) and the bonding system.
The photovoltaic technology uses different kinds of substrates: glass, metal (stainless steel) and plastic. The glass technology is the most used and now offers the best cost-performance ratio. Since it is not sure however that it is the best-suited technology for the hybrid application, it is important to keep in mind the other two technologies. The metal substrate recently achieved very good efficiencies (8.5 % for standard modules) but is only provided by one American manufacturer. The plastic substrate technology is now commercially available from an American company. This product is mainly suited for small power applications and the production capacity has not yet reached a threshold that would considerably decrease costs.
For the thermal exchanger, the standard technology is now based on solar fins made of copper. The feasibility study shows that the metal exchanger offers right now the best cost-performance ratio. We will however keep the option open to make a second thermal exchanger variant made of technical plastic.
For the bonding, they are three possibilities:

- use the standard encapsulation material EVA connected to a series of aging tests
- find out new ways of implementing silicone mastic which can be easily charged in order to increase thermal conductivity
- testing other kinds of resins which are a good compromise between silicone and EVA.

No. Description	Market: Private buildings (one family)	Private buildings (many families)	Private residences	Holiday complexes	Holiday buildings	Office and administrative buildings	Residential buildings	Industrial buildings	Heat use: Hot water	Space heating	Pre-heating and combinated	Seasonal stocking	Anti-freezing protection of remote buildings	Surface [m²]	Electricity use: Grid connection	Grid connection with integrated inverter	Grid failure protection	Lighting, radio, TV,...	Integrated controlling and fluid powering	Power [kW]
1 Solar home system - grid or remote	•	•	•						•	•			•	4 .. 40	•	•	•	•	•	0.2 ... 2.0
2 Solar kit - grid or remote	•	•							•					3 .. 6	•	•	•	•	•	0.2 .. 0.5
3 * Integrated controlling and fluid powering	•	•	•	•	•	•	•	•	•					3 .. 40					•	0.02 .. 0.2
4 High architectural value systems			•	•		•	•	•	•	•	•	•		20 .. 500	•	•				1 ... 100
5 Large systems, evt. unglazed					•	•	•	•	•	•	•	•		50 ... 10000	•					3.3 ... 500

* Remark: No.3 is included in No.1 and No.2 (count 17 W for 5m 2 collector)

Fig. 4. The potential market is segmented in 5 application categories. Each segment is described with customer sector, heat use, typical size, electricity use and typical resulting electrical power.

4. MARKET ASSESSMENT

In order to assess the potential market for hybrid solar collectors, we distinguished 5 different application fields (see Fig. 4).

The first field concerns private homes and comprises surfaces between 4 and 40m^2. The thermal energy is here used for space heating, for domestic hot water (DHW) and for anti-freezing protection. Depending on the location of the house, the associated PV system can feed the electrical grid or charge batteries for domestic electricity.

The second category concerns private homes, too. The difference results from system standardization: it is the "hybrid solar kit" with a typical size of 5m^2. This size will be ideal for DHW for a single family home. On the side of electricity use, both grid connection and battery charging will be feasible, depending on the location of the building.

The third category refers to standard solar kits whose controls and circulating pump power are supplied by a PV module. With the developed technology, the integration of the PV module into the collector (typical power for low flow pump: 17W S.T.C. for a 5m^2 solar system) will be made feasible.

The fourth category refers to systems where special attention has been given to the architectural integration. These systems are called "high architectural value systems". In this category, the newly available technology will make possible construction similar to the "Building TH 89" at the Alpnach Airport (Switzerland) which obtained one of the Swiss Solar Prices in 1996. The new generation will nevertheless offer a drastically improved thermal efficiency.

In the last category called "medium and large systems" larger systems are represented (size above 50 m^2) where thermal energy is mainly used for pre-heating, in combination with traditional heating systems.The latter two categories concern grid-connected PV systems.

Based on different specialized market surveys and with a rigorous evaluation method (described in details in the final report of the first phase [1]), we obtained a potential niche market based on a scenario "business as usual" of 11 MW per year of modules for the construction of hybrid modules. It has thus been shown that the hybrid collector can rapidly become an interesting complement to the actual PV market.

5. CONCLUSION

Although the idea of producing a solar collector for both electricity and heat is not new, the new generation is based on a totally new concept. The feasibility study has collected much information about all important aspects (costs, technology, market, contacts with industries, ...) to prove that further development is worth being done. The follow-up will now focus on three points:

- better know and improve the absorption of thin film modules
- better know the behavior of thin film modules under high temperatures for long periods
- obtain the necessary know-how for the best way of bonding solar devices to heat exchangers.

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