Solar radiation as a source of heat

Heat from the Sun

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Dr. Włodzimierz Smolec, a staff member at the Institute of Chemical Engineering, Polish Academy of Sciences, in Gliwice, studies solar air heating collectors. In 2000 he published the book *Fototermiczna konwersja energii słonecznej* (Photothermal Conversion of Solar Energy)

Rising global temperatures, mounting energy prices, increasing atmospheric pollution... all these problems might be alleviated by better harnessing the energy from the Sun

One factor that is of fundamental importance in harnessing the energy of solar radiation is the price of the heat so obtained. Because the quantity of energy borne by solar radiation is relatively small (1367 W/m^2 outside the Earth's atmosphere), solar systems have to be large to be able to generate heat in amounts of practical significance. The objective of research on harnessing solar radiation is not only to reduce the cost of the obtained heat, but also to curb the demand for energy (not just thermal energy). We should also note the environmental aspect: each kilowatt hour of solar-generated electricity enables from 0.8 to 1 kg of carbon dioxide emissions to be avoided.

Solar liquid heating collectors

Solar hot water systems can already now be found in many locations in Poland. The main use of this technology is in residential buildings where the demand for hot water has a large impact on energy bills. Most commonly used solar collectors are flat-plate liquid heating collectors. They supply hot water and their typical operating temperature is around 40-60°C. The most important component of the collector is the absorber made of copper, aluminium, steel or plastic. This absorber converts solar radiation into heat, which is collected by heat transfer fluid flowing through flow tubes that are attached to it. The flow tubes are spaced several centimeters apart, with the absorber surface between them acting as 'fins' that absorb the heat and conduct it to the tubes. Cover plates (called glazing) usually made of glass

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Solar water heating systems designed to be utilized on a year-round basis use a heat transfer fluid with a low freezing point to collect heat from the absorber. A heat exchanger is used to transfer the heat from the heat transfer fluid to the water

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Absorber plates in solar collectors are commonly covered with "selective coatings", which absorb and retain heat better than ordinary black matte paint. Solar collectors are not used just in countries situated in a warm climate zone: they can be frequently encountered in Scandinavian countries

reduce the absorber's convective and radiative heat losses to outside air. The absorber plate is insulated on the bottom and edges with thermal insulating materials. The absorber's surface area is usually around 2 m^2. Collectors are joined together into arrays.

Curbing losses

The solar radiation that falls on the glass cover is partially reflected and absorbed by it. These losses in solar radiation reduce the collector heat output. The radiation losses caused by reflection can be reduced by antireflection coatings made of porous silica or alumina deposited on the collector's glass cover. These materials are transparent to solar radiation and their index of refraction is less than that of the glass. The thickness of the coatings is less than the wavelength of the solar radiation.

Glass, the material most commonly used as a cover material in solar collectors, contains iron oxides strongly absorbing solar radiation. To reduce the radiation losses caused by absorption now collector glass covers are often made of special low-iron glass.

The efficiency of flat-plate collector can be enhanced by the convection suppression in air gap between the absorber plate and the glazing. This effect is obtained by inserting transparent honeycomb insulation in the gap. Such insulation is made of transparent plastics (for example polycarbonate) usually taking the form of thin-walled, elongated cells, in a structure reminiscent of a honeycomb. The air trapped inside the resulting cells is practically immobile and heat can only flow through such materials by conduction and radiation. Similar transparent insulation resistant to higher temperatures consists of glass capillaries inserted between two glass panes. The capillaries as well as the glass panes are made of low-iron glass. Transparent honeycomb and capillar insulations belong to the broad, high-tech category of transparent insulating materials (TIM).

Even greater efficiency can be achieved with an evacuated-tube collector in which a selective absorber is contained within a glass cylindric envelope that is evacuated to eliminate convection and conduction heat losses from the absorber. The glass envelope (called tube) is around 2 m long and around 7 cm in diameter. The heat generated in the absorber first gets collected via an attached heat pipe, which then passes it on to the heated water. The heat pipe is a heat transfer device that consists of a sealed chamber containing a liquid and its vapor. Heat is transferred by liquid evaporation at the evaporator (the hot, lower end of the chamber) which is attached to the absorber plate. The vapor flows to the condenser (the cool, upper end of the chamber) and condensates, releasing the heat. The liquid is returned to the evaporator by gravity. From the condenser the heat is transferred to heated water. A collector module usually contains some twenty-odd evacuated tubes.

Solar collectors can be installed as a large, flat arrays atop a sloping roof or mounted on the ground. New perspectives are now opening up for architectural integration of solar collectors also into south-facing façades of buildings. These perspectives ensue from the development of advanced colored glazings for solar collectors. Colored glazings are glass panes covered with thin films of silicon oxide and titanium oxide. Due to interference the solar radiation re-

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An evacuated-tube collector - this module contains 30 evacuated tubes

flected from these glazings appears colored. The produced coatings combine a bright colored reflection with an acceptable solar transmittance. Solar collectors equipped with colored glazing have become attractive option for both residents and architects, as compared with standard collectors with transparent glazing through which the black absorber can be seen.

Continuous development in solar thermal technologies results in decreasing costs of domestic hot water production. Given the kind of climate conditions present in Greece, the initial costs of a water heating systems have dropped by nearly 20% since 1980, the amount of heat produced per unit of collector surface has increased by more than 50%, and the cost of heat production has dropped by approx. 45%. Yet contrary to what one might expect, quite decent conditions for directly harnessing solar energy can be found in Poland as well. Yearly global solar horizontal irradiation varies in different regions of the country, of course, varying from 900 to 1200 kWh/m^2.

Solar air heating collectors

A flat-plate solar air heater is a simple device to heat air by utilizing solar energy, which has many applications in drying agricultural products, such as seeds, fruits and vegetables. Also, solar air heaters are utilized for space heating. A conventional solar air heater mainly consists of an absorber plate, a glass or plastic cover fixed over it. The system is insulated thermally from the back and from the sides. The air flows either over or below the absorber and collects the heat. The energy collection efficiency has been found to be generally poor due to unfavourable thermophysical properties of air. In order to enhance the energy collection efficiency various methods have been developed. These methods include means leading to increased heat transfer area between the absorber plate and the air as well as modification of absorber plate surface shape leading to increased intensity of heat transfer to the heated air.

Relatively frequently (although not yet in Poland), solar air heaters are utilized for space heating in school buildings. Such buildings are only in use during the daytime, which means that the heat generated by the collectors in the daytime hours does not need to be stored away for the evening or nighttime hours.

Solar hot water and air heating systems that utilize collectors employ a controlled circulating pump or fan to drive the heat transfer fluid or air heated by sun. These systems are called active solar systems.

Solar space heating

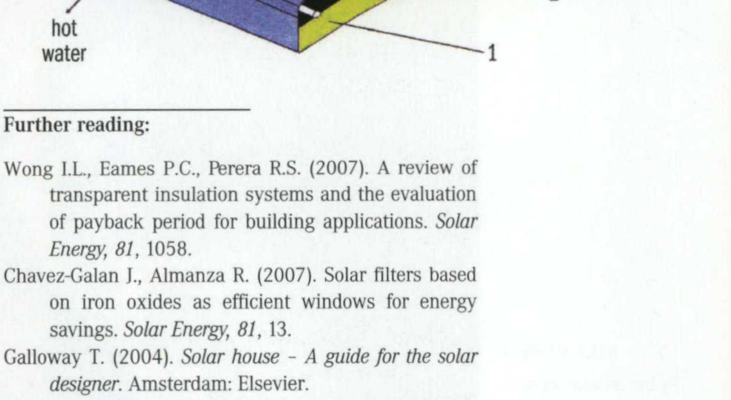
Within Poland's climate zone, solar liquid systems for hot water and space heating designed to satisfy heating demands on a year-round basis are still of an experimental nature. The costs involved are high because a large number of collectors needs to be used. Moreover, such installations require a seasonal heat storage facility to store heat that is collected in the summer until it is needed in the winter. Heat is stored underground in water filled rock caverns, tanks, aquifers or in earth, rocks etc. During the winter period stored heat is recollected using a heat pump. Heat pumps are also utilized to recover waste heat, collected from used air expelled out of the building through its ventilation system and from used water before its release into the sewage system.

Due to the high costs of such year-round heating systems, so called passive solar heating systems are used to provide supplementary heating for homes, aiming to partially, rather than fully, satisfy their demand for thermal energy. In a passive system a part of the building itself (internal or external walls, floors/ceilings) serve as the solar collector and thermal storage, and the use of fans or pumps is either relatively small or non-existent. Part of the solar heat collected by biuldings' walls is then transferred to the interior by radiation or solar heated air circulate due to buoyancy-drive natural convection. Passive solar systems may meet 10-15% of the heat demand in existing European housing stock. Only a few of solar passive systems can be encountered in Poland. They are atriums and greenhouses directly attached to the southern faces of houses.

In order to reduce heat consumption for space heating the aforementioned transparent insulation materials are utilized in building design. TIMs are used to replace standard opaque insulation materials. The thickness of insulation materials used is typically around 25-30 cm. TIMs not only perform similar functions to opaque insulation materials: they allow solar transmittance of more then 50%. The heat losses of the building are reduced and the solar radiation transmitted through the TIM is converted into usable heat at the dark painted wall surfaces. Wherever there is a concern that the building might overheat in the summer, an air gap can be left between the thermal insulation and the wall itself. The air circulating through that gap from the surroundings then prevents the building from overheating.

Progress in solar thermal technologies

Research underway for the past 30 years has made great advances in developing technologies for harnessing solar energy, yielding a significant drop in the costs of the obtained heat and broadening the potential for putting research findings to practical application. Such studies are being conducted by an increasing number of research centers, and the number of papers published is rising dynamically. The main factor stimulating the development of research in the field is the fact that harnessing solar energy does not involve carbon dioxide emissions. One may also expect the recent surge in oil prices to once again spur the development of research on solar energy and other renewable energy sources, much like the effect of the oil price increases back in the 1970s. ■



A schematic presentation of a flat-plate solar liquid collector: 1) thermal insulation, 2) absorber, 3) flow tubes, 4) glazing, 5) enclosure. Arrows illustrate the direction of fluid flow

Further reading:

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