SOLAR ENERGY IN BUILDINGS

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1. Introduction

The overall energy demand for buildings – and the fossil resources exploited to fulfil this demand – represent a large fraction of the energy consumption in the industrialised countries. By far the largest amount is used for heating and hot water preparation, but also lighting, cooking, and auxiliary appliances play an important role in the energy-related emissions.

This fact has to be kept in mind, when solar energy utilisation in buildings is envisaged: Not only that the various needs must be tackled properly, making the task rather difficult and complex. Moreover, the proper treatment of the energy-related problems in buildings cannot be limited to the development of novel techniques and design methods: By far more important is the reduction of the specific energy consumption of existing buildings. In Table 1 the average demand of a conventionally built dwelling has been compiled against the demand for a building according to the IEA Task 13 standards (1994 - 1996) and for a house of contemporary design.
The reduction of energy utilisation is apparent. But even if this trend is impressive, the question, whether a zero-energy solution might be feasible, cannot be answered generally. An assessment of total energy demand for a buildings designed following different standards leads to minima for low energy houses - not for the ones with zero energy demand. In the latter case the (energetic) expenditures for building materials and for seasonal storage exceed the overall energy saved within the lifetime.

Table 1: Progress in specific energy demand

Building status			**konventional**	**IEA, Task 13**	**optimised**
Total spec. energy demand p.a.		**kWh/(m²,a)**	**140 ... 200**	**20 ... 70**	**below 20**
rate of fossil to solar contrib.			**100 / -**	**60 / 40**	**25 / 75**
Energy Input for:	heating	**%**	50	35	15
	DHW		25	28	40
	electr. appl.		25	37	45

The breakdown of the energy use shows clearly that with a more efficient thermal insulation of the building the demand for space heating is reduced, whilst – in comparison - other consumption factors become more striking: demand for domestic hot water and electricity consumption can only slightly be influenced by the habits of the residents and are more ore less invariable, as long as not very efficient technologies are used. This gives hints for future activities, since the relative importance of the constituents mentioned increases with the diminishing overall energy demand.

Certainly, any such judgement is subject to the basic assumptions applied. This is for instance the case, where more favourable climatic conditions prevail - or if the user-oriented parameters, e.g. the interior temperature levels during the cold season are modified.

2. Methods to reduce the Energy Demand

According to the various demand figures and building concepts also different means to influence the thermal energy losses and the additional energy demand in buildings are common. The following listing summarises the basic strategies, each of which can be applied as an isolated measure. More common – still - is a combined use (depending on the type of the building and the users' requirements).

- Design and orientation of the building with respect to the solar incidence; proper arrangement of rooms.
- Advanced insulation techniques and optimisation of the building structures.
- High quality windows.
- Active solar energy conversion:
  Domestic Hot Water preparation (in combination with proper storage methods)
  Building integrated PV
- Integrated auxiliary (ventilation, shading, light directing) units and controls.
- Efficient heating (and/or air conditioning; cooling) systems.

The broad variety of utilisation schemes makes optimisation processes necessary. The arguments supporting any "best solution" have to be judged on the basic requirements. Depending on the purpose the building is planned for, the geographic location, and the consumers' demands various parameters may contribute to the overall performance.

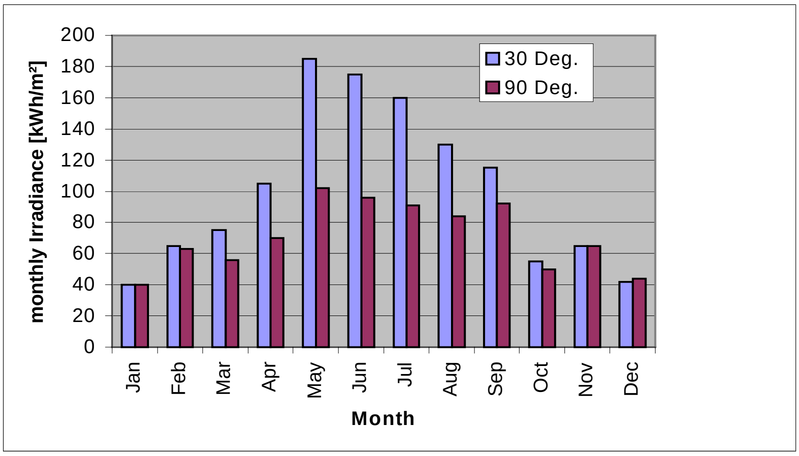


Diagram 1:
Monthly Irradiance on inclined and vertical surfaces (Latitude: ~50 Deg. N)

Diagram 1 illustrates the influence of the solar incident angle for an inclined surface and for a vertical facade during the year – demonstrating how much the orientation of building structures might influence the solar gain. Similar calculations can be made for any deviation from the "true south" orientation.
The effect of such irradiance on the net energy gain depends on the building material used and the structure of the building. Diagram 2 illustrates this with regard to massive and glazed surfaces, compiled from an example of an office building: With a higher glazing ratio of the facade the heating and cooling demand is increasing steadily, whilst the lighting energy is decreasing. The overall energy needed is minimal at a glazing ratio of 35 to 45 %, depending on the characteristics of the windows.

In Diagram 3 the thermal energy demand for heating and for domestic water heating is put against the possible inputs from passive and active solar processes. The compilation is valid for locations in central Europe (latitude about 50^o N) and shows that using contemporary methods to exploit renewable energy sources a full coverage of the heat demand is not possible during the winter months, but that an overall energy saving of about 20 to 30% is viable. Any such assessment is subject to the economic parameters, which is mainly the fuel costs and the costs for solar appliances and storage concepts. Moreover, if heating using biomass (wood chips, pellets, in some cases also biogas) is taken into account, a full coverage of the energetic demand for heating is viable and – at least in some regions – also economically competitive.

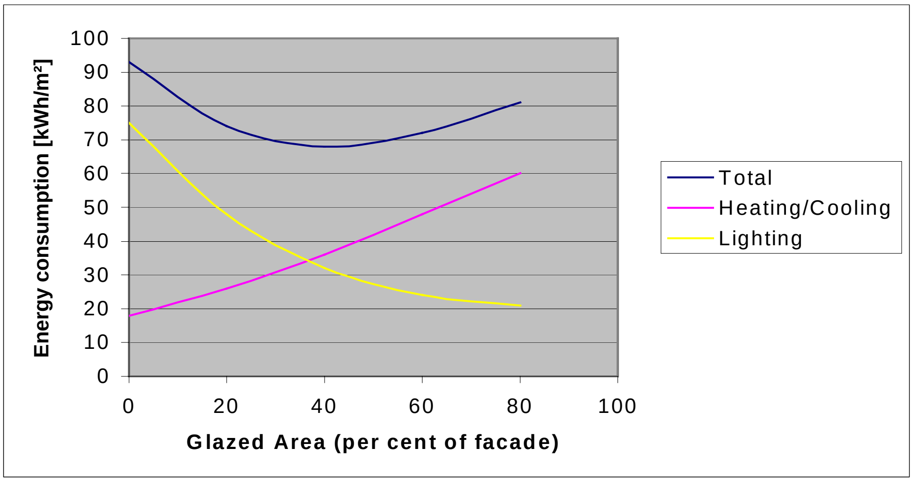
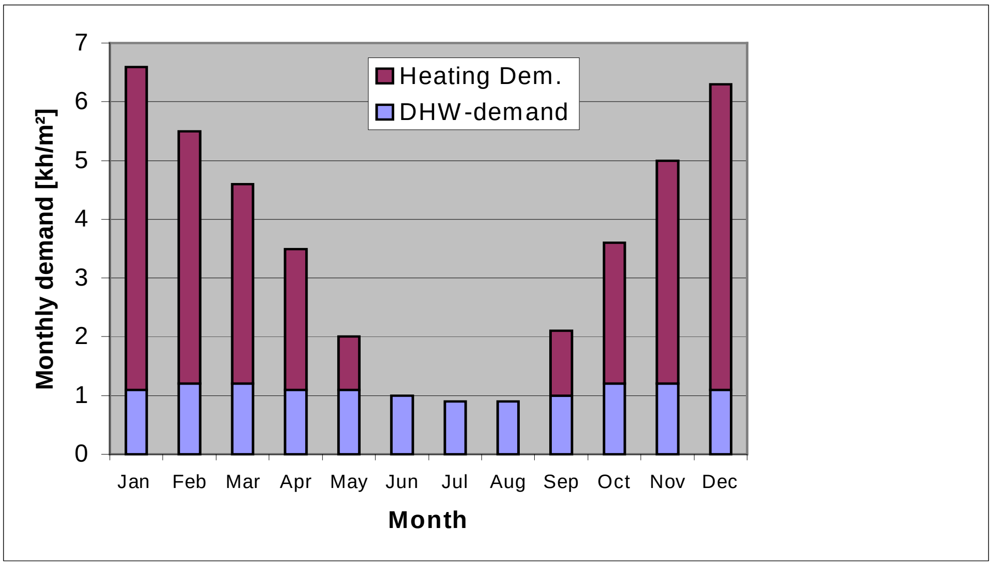


Diagram 2:
Specific Energy Consumption (per m² of the facade) as a Function of the Glazed Area



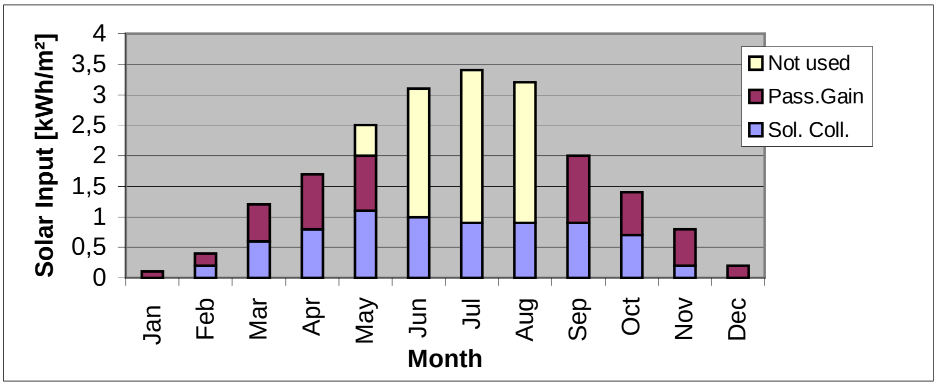


Diagram 3:
Energy Consumption (per m² living space and per month) for DHW and Heating (upper part)
Energy Input for Hot Water Preparation and Space Heating from Insolation (below)
Note: Energy not used (in summer times) indicates that there may be an overheating problem

In Diagram 3 the thermal energy demand for heating and for domestic water warming is put against the possible inputs from passive and active solar processes. The compilation is valid for locations in central Europe (latitude about 50 deg. N) and shows that using contemporary methods to exploit renewable energy sources a coverage of the heat demand is not possible during the winter months, but that an overall energy saving of up to 100% is viable during the summer. Over the year the energy saving by the indicated means is about 13 kWh/(m²,a), which in the case shown reduces the overall thermal energy demand for the building from 43 kWh/(m²,a) to 30 kWh/(m²,a)

The occurrence of excess heat input in the summer season may necessitate additional measures, e.g. shading of the facade, forced ventilation, etc., but there is also an opportunity to store the heat in an adequate way for the cold season. Regrettably long-term storage methods are quit cost-intensive, especially if to they were not planned and built in the erection phase of the building. An example of a very appealing solution (from a technical and architectural point of view) is shown in Figure 1, where solar heat collectors (each of the buildings has 47 m² of heat collecting area on the south oriented facade) were combined with large water storage tanks (10 m³ for the heating system and 0,8 m³ for DHW). By that means the residents in the two houses report a quite high coverage of the thermal energy demand (70% for heating, 90% for hot water), which indicates that also the overall design of the building contributes to the impressive results.

Anyway, any such assessment is subject to the economic parameters, which is mainly the fuel costs and the costs for solar appliances - and storage concepts.

Shading, ventilation, circulation of heat exchange media, and many other appliances indicate that the exploitation of renewable energy is not a “simple” task, necessitating some additional means and also some control devices to warrant satisfactory functioning and operation of the solar components. Besides the common equipment for heating (boilers and burners) electrical and heat driven heat pumps become of increasing importance. But also other techniques may be attractive, be it the shading devices for the building shell, PV- elements at the facade or on the roof, etc. Figure 2 illustrates such an application.

Figure 1:
Buildings with large solar heat collectors for space heating and hot water preparation

3. Energy Savings in Existing Buildings

Recently, many of the proposed methods to reduce the energy demand have also been tested in combination with conventional building structures. The results are promising, even if the intended low energy data of new houses are presently out of reach for traditionally built dwellings. This is mainly due to the fact that the existing structures impose compromises with respect to various features. Some points to be mentioned are: Tightness of the building shell, existence of "cool spots", limiting factors to use low temperature heating systems, etc.

To reduce further the energy requirements of old buildings some additional measures have been proposed. One promising method is the Transparent Insulation (TWD), which can be applied to stone or brick walls or to building shells of low thermal quality. TWD in acting in two directions: It affects the thermal conductivity of the wall and it increases the solar gain. Figure 3 shows an example of a building, which was reconditioned using TWD fixed on part of the exposed walls.

Figure 2:
PV modules mounted on a facade as shading elements and for electricity generation

Figure 3:
Retrofitted building with Transparent Insulation elements