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ADVANCED SOLAR LOW-ENERGY BUILDINGS
TASK 13 OF IEA´S SOLAR HEATING AND COOLING PROGRAMME

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INTRODUCTION

The energy consumption for heating has in many countries been greatly reduced over the last few years. This is mostly achieved by the use of traditional energy conservation and solar technologies. The total energy consumption, especially in residential buildings, is, however, still large and warrants considerable effort. To obtain a significant further reduction in the energy consumption for heating, and also to reduce the consumption for cooling, ventilation, and lighting, it has become necessary to develop new building concepts. Such new concepts require the use of new materials, components, and systems.

Recent advances in several areas of research have resulted in concepts and products that can potentially be used. For instance, the developments in material technology, with products such as transparent insulation, is having a considerable impact. The developments in other areas also need to be explored, and the most promising materials, components, and systems need to be analyzed, tested, and developed for the purpose of integrating them in whole building concepts.

The experiences gained and developments made with the various technologies are not automatically available to groups doing research in other areas. A joint project such as an IEA task, with participants with contacts within different fields, therefore greatly increases the possibility that all potentially usable ideas are explored. At the same time the testing facilities and analysis capabilities existing within the various countries can be utilized by the group as a whole.

THE IEA TASK

Task 13 was started for this purpose. Its official objective is "to advance solar building technologies through the identification, development, and testing of new and innovative concepts which have the potential for eliminating or minimizing the use of purchased energy in residential buildings while maintaining acceptable comfort levels". It deals with the application of both passive and active solar technologies for space heating of residential buildings. The use of passive and active solar concepts for cooling, ventilation and lighting is also addressed, as well as advanced energy conservation measures that reduce heating and cooling loads.

The emphasis is on innovation and long-range (after the year 2000) cost-effectiveness. The materials, components, systems, and concepts considered need therefore not be currently feasible, economical, or on the mass market today, allowing the participants to look at totally new solutions.

The Task was started in 1989 and will last through 1994. Fifteen countries are participating, including most of the western European countries, plus Canada, Japan, and the USA. The minimum level of effort required for participation is one manyear per year for the duration of the Task, which means that the Task as a whole involves an effort of more than 75 manyears.

During the first half of the Task, emphasis has been placed on the development of whole building concepts. A number of design workshops have therefore been conducted in conjunction with the semiannual task meetings. At these workshops, the countries have presented the design concepts they have developed. The concepts have been discussed and criticized, and improvements have been suggested, ensuring that the expertise of the group as a whole has been utilized. Between meetings the concepts have been revised and reanalyzed. By now most of the countries have buildable designs.

THE TECHNOLOGIES USED

As part of the concept development a number of technologies have been studied and documented. The materials, systems, and components that appear to be of most interest to the Participants are:

- Advanced glazings
- Transparent insulation
- Dynamic insulation
- Phase-change storage materials
- Integrated mechanical systems
- Domotique type control systems
- Solar cells

Advanced glazings:

Advanced glazings, glazings with exceptionally low U-values and with solar and daylight transmissivities equivalent to those for conventional glazing, are extensively used. The most common types of advanced glazings are:

- "Superwindows"	Multiple glazings with low-emissivity coatings and krypton or argon gas filling
- "Vacuum windows"	Two or more glazings with the space in between evacuated
- Aerogel windows	Two glazings with the space in between filled with aerogel

As windows strongly influence the energy balance, the new glazings dramatically improve the energy performance. Most of the Task 13 concepts consequently use advanced glazings of one type or another. The majority uses "superwindows", which appears to be the type most readily available, while one of the German concepts uses windows filled with xenon, and both the Danish concepts use windows filled with aerogel.

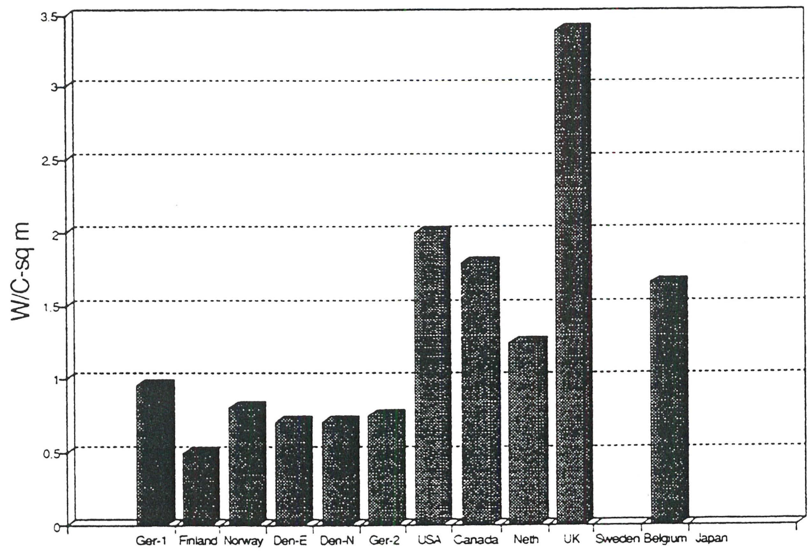

Fig.1: U-values for the windows used in the Task 13 buildings.

Socalled "smart windows", with glazing that has controllable optical properties, have been considered for the purpose of shading such windows. These have a coating that is sensitive either to sunlight intensity, temperature, or a small electric current and that changes from clear to reflective or absorptive and back again when influenced by these stimuli. The Canadian concept, for instance, uses a thermocromic coating with a switching temperature of 24° on some clerestory and southfacing windows to reduce solar gain on sunny summer days.

As this technology is not readily available in all the countries, other systems for optical and thermal control are also considered:

The Swedes are, for instance, testing a concept they call "the Magic Window". This is a three-dimensional window containing a movable reflector. The reflector also functions as a shading device and as an insulating shutter, reducing both heat gain in the summer and heat loss in the winter.

The Germans have, on the other hand, been testing a water cooled shading device they have developed for use in combination with traditional glazing. This device resembles a venetian blind with the slats replaced by solar collector fin tubes. The tubes have a selective surface on one side and are painted white on the other. At night the blinds are closed with the selective surface facing out, in effect creating a triple-glazed window with a low-E coating. During winter days the blinds can be adjusted to vary the amount of solar radiation entering, and during summer days they can be switched to have the white side out to prevent overheating. Water circulated through the tubes in the blinds is used to supply domestic hot water and to cool the blinds.

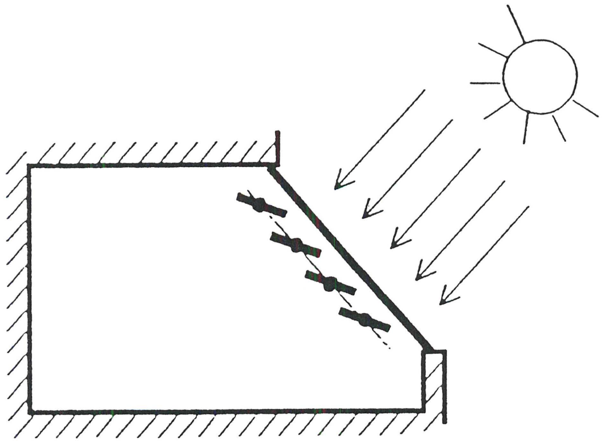

Fig.2: A sketch of the German water-cooled shading device.

Transparent insulation:

Transparent insulation materials, i.e. materials with low U-values and high solar transmissivities, are clearly very popular in most of the participating countries. The two major types receiving attention are honeycomb and aerogel materials. A number of parametric studies has been performed on these, especially by Denmark, Germany, and the Netherlands, and the results are quite promising. Many of the building concepts developed consequently use transparent insulation in one way or another. The Belgian concept, for instance, uses cloudgel in skylights, both the Danish concepts use monolithic aerogel in solar walls, the Dutch concept will use either granulated aerogel or a honeycomb type in transparent wall elements, and the Norwegian concept uses a honeycomb type in a sunspace.

Dynamic insulation:

Dynamic insulation, a concept where a forced flow of air is directed through the thermal insulation layer for the purpose of recovering heat lost, thereby preheating the incoming air, has also received a fair amount of attention. It has been studied in detail, especially in Finland.

Simulation results showed a theoretical potential reduction in heating energy consumption of 20-25%. Testing of such components in the laboratory showed a much smaller reduction, however. It appears that it is extremely difficult to achieve and maintain a uniformly distributed air flow through the insulation. Consequently no country has taken the step to include it in their building concept so far.

Storage materials:

Phase change storage materials, primarily incorporated in wood, gypsum board, and concrete in order to increase the thermal capacity of the materials, is also a popular subject of investigation. The Japanese concept was simulated both with a low mass and with a high mass structure, and the results showed that the high mass case uses 20% less energy for heating and cooling. Building materials with PCMs incorporated are now being considered for this concept.

Most of the building concepts use more conventional diurnal storage, however. The Swedish concept uses hollow core concrete slabs, and the US concept uses wall elements with 5 cm concrete on the interior as thermal mass.

Seasonal storage is also being considered. The thermal energy demand is, due to the advanced conservation techniques used, quite low, but it is reduced to a short period of the year when there is virtually no sun. The Germans are consequently developing a seasonal storage system for one building, while the Swedes are considering a system that can be connected to a large scale seasonal storage plant.

Mechanical systems:

In most concepts both solar gains and heat recovered from exhaust air and waste water is used. The concepts therefore use some type of integrated mechanical system, with either heat pumps or heat recovery units or both. The US concept uses a heat pump and heat recovery combination to provide both heating, cooling, ventilation air and hot water. One of the most advanced systems, using a heat pump with ice phase change storage in combination with ventilation air and grey water heat recovery, is used in the first Canadian concept.

Separate heat pumps are also popular. The Finnish concept uses a ground coupled heat pump, the Japanese concept a collector driven one, and the Norwegian concept one using both a sunspace collector and a ground coil. The ground coil functions to a certain extent as seasonal storage.

Many concepts, such as the Belgian, Canadian, Danish, German, Japanese, and Dutch concepts, also use active water collectors to cover part of the heating and hot water loads, and the Dutch concept uses an innovative mechanical system integrated in prefabricated wall elements for heating and ventilation.

Control systems:

"Domotique" type intelligent home automation systems are required to run many of these integrated systems. Home automation systems provide a computerized integration of the various building systems and ensure proper control of indoor climate, optimal use of solar energy, and minimized energy consumption. In addition they function as communication networks and security systems. As the building concepts are quite complex, and as many of them incorporate "intelligent" building components such as "smart windows", the requirements of control also increase.

The Belgian concept is so far the only one actually using such an advanced system. This system controls both heating, ventilation, shading, and lighting, and includes some security functions.

Solar cells:

As the buildings require less and less thermal energy, the electricity demand is becoming more important. In fact, in some cases it is taking over. For instance, in the Norwegian concept, the lights and equipment load constitutes more than half of the total load. In this concept, the heating need is covered by a heatpump, reducing all energy needs to the need for electricity only. The concept therefore uses photovoltaics to cover part of the electrical load.

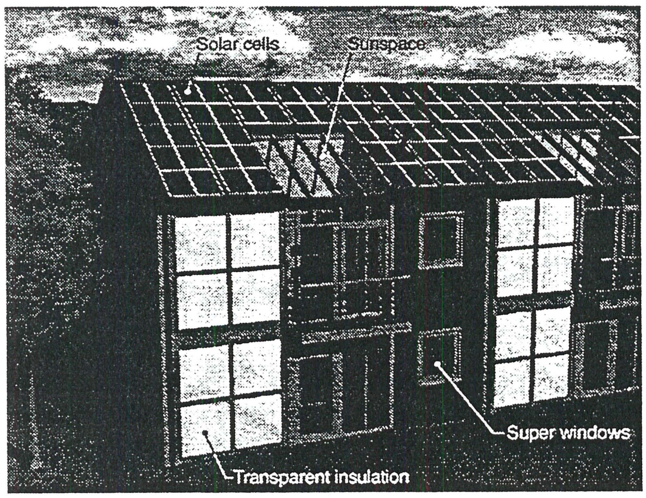

Fig.3: A computer drawing of the Norwegian building.

Several of the other concepts also use photovoltaics for some applications. The Japanese concept, for instance, uses a PV operated air conditioning unit, and the Canadian concept uses a PV operated fan for the solar water collector. The Canadian concept also includes PV powered outdoor lighting.

In general, appliances, lights and equipment is continuously becoming a larger part of the load, and more research is being concentrated on these aspects. Most of the countries emphasize energy load levelling strategies as well as energy savings strategies. There is, consequently, also a great interest in energy-efficient equipment, appliances, and lighting. Such equipment is documented but has not been subject to research within the Task, however.

THE EXPERIMENTAL DWELLINGS

At this point most of the participating countries have developed and analyzed quite specific building designs. Thirteen of the countries also have sites and builders, and construction of the first experimental dwellings has started.

The dwelling types vary from single family detached houses to a large apartment building. The majority of the projects are relatively small, however. The systems used in the buildings vary significantly, partly due to differences in climate and context, but all the concepts include one or more of the technologies discussed above.

A cross comparison of the energy figures for the various designs show that most of the concepts have a calculated total annual energy consumption of approximately 30 kWh/m^2 floor area. This means that the heating consumption is quite close to zero. It appears that 30 kWh/m^2 is the minimum consumption reachable without the use of seasonal storage. The only concept with a significantly lower total consumption is the one German project that does use seasonal storage.

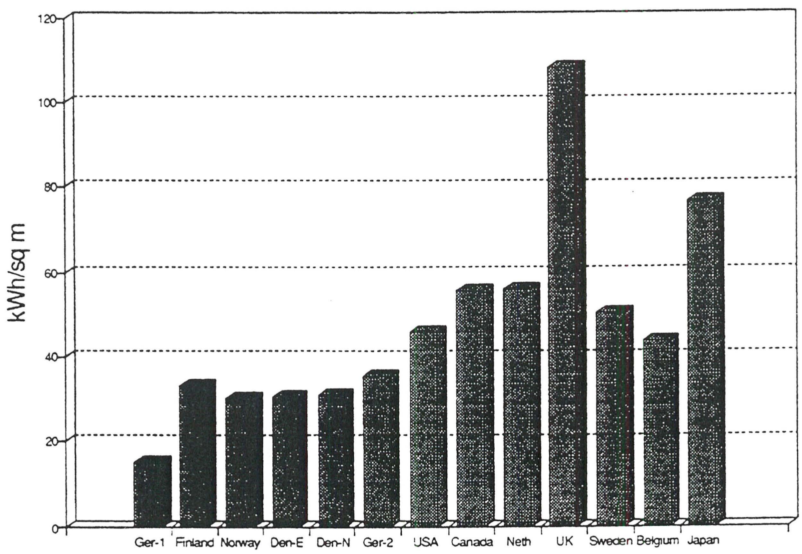

Fig.4: Total energy use for the Task 13 buildings.

The climates of the participating countries vary from very cold, in the Nordic countries and Canada, to quite warm, in parts of the USA and Italy. Still, the consumption does not differ very much from country to country, i.e. it appears to be relatively independent of climate. This may partially be a result of the fact that each country's target for energy consumption has been set relative to the standards in that specific country. For instance, the insulation levels are traditionally very low in Belgium and high in Norway. The energy consumption per square meter therefore does not differ as much as one would expect when looking at the climatic differences. The amount of additional insulation used in the Task 13 concepts is also based on the local context rather than on the general savings potential. The resulting energy consumption is therefore still not very climate dependent.

Only one of the building concepts has a target of zero heating energy. It is quite possible to reach such a goal, but in most cases the systems that would have to be used would clearly not be cost effective. Some of the more innovative ideas developed in the Task showed a very large energy savings potential. But, most countries found it difficult to find builders willing to take risks on new and possibly costly systems and components. Quite a few bright ideas were therefore dropped on the way to the construction site.

One example of this is the Japanese building, which is already completed. This building could not be built with all the systems studied during the design phase. However, the Japanese have simulated the same concept with both solar water collectors and photovoltaic panels, showing that the total energy consumption can be reduced to 33 kWh/m^2. At this point they are looking at adding some of these features to the finished house.

COMPLETION OF THE TASK

As mentioned above, many of the countries have now started to build their Task 13 buildings. Construction has been a bit delayed due to the common difficulties of finding sites, builders, and funding, but quite a few buildings will be completed this year. Then monitoring will start. As these buildings are meant to be experimental buildings and not merely demonstration projects, the level of monitoring will be quite extensive. By the end of the monitoring period, i.e. by the end of Task 13, a lot more should be known about the new technologies and about how to reach extremely low levels of energy consumption in residential buildings.

Dissemination of the results to the building community has been carefully planned and includes a number of technical reports and a final sourcebook summarizing most of the work done in the Task. The most important way of disseminating the results will probably be through presentation of built projects, however.

Two symposia are planned for this purpose. The first one was conducted in Germany in conjunction with a CIB Symposium in March this year. At that one, the building concepts and the simulation results were presented. At the second one, at the very end of the Task, in late 1994 or early 1995, the actually built projects will be presented.

ACKNOWLEDGEMENTS

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Table 1: Status of the experimental buildings.

Country:	Design:	Construction: Start:	Finish:
Austria	Apartment building	Fall 93	?
Belgium/CEC	Town house	April 93	December 93
Canada	Advanced house	1989	1990
	Green home	September 92	April 93
Denmark	Row houses	October 93	March 94
Finland	Single family house	June 93	June 94
Germany	Duplex	August 92	July 93
	Row house	June 93	April 94
Italy	?	?	
Japan	Single family house	February 92	June 92
Netherlands	Apartment building	September 93	December 94
Norway	Row house	January 93	June 93
Sweden	Single family house	April 94	October 94
Switzerland	Duplex	April 94	April 95
UK	Retrofit	June 92	
USA	Grand Canyon house	June 93	October 93
	Yosemite house	June 93	October 93

Most of the buildings are very well insulated, and much attention is given to construction details and to how to ensure airtightness and avoid thermal bridges. Many of the buildings also have a rather compact shape. A few, as for instance the German duplex and the Dutch apartment building, have maximized southern exposure by the use of fan shaped floor plans.

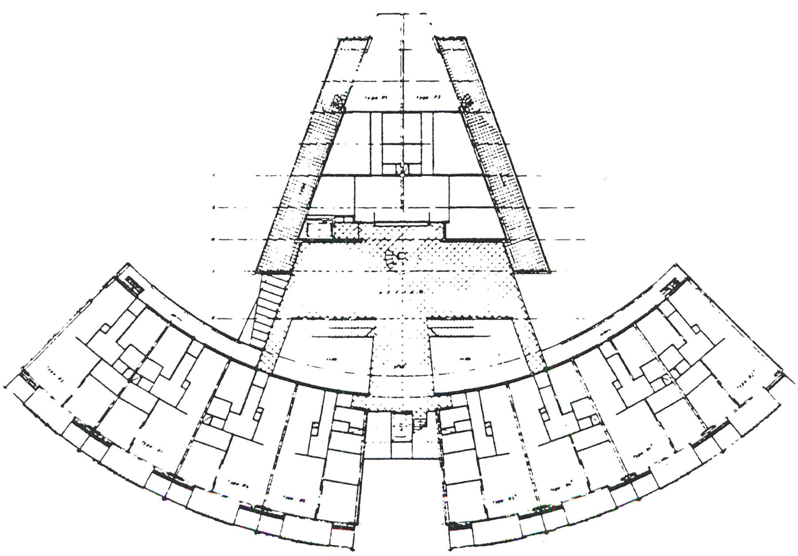

Fig.4: A floor plan for the Dutch apartment building.