THE STATE OF SOLAR TECHNOLOGY DEVELOPMENTS IN THE FEDERAL REPUBLIC OF GERMANY

by

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SUMMARY

The activities of the West German industry in the solar energy program are presented.

RESUM

La indústria alemanya davant el programa d'expansió de l'energia solar.

GENERAL INTRODUCTION

As recently as five years ago, the utilization of solar energy in our country could not even be discussed. Only companies involved in the space program were conducting developmental research. However, three years ago, serious work began on the use of solar energy for water and space heating.

The reason for the sharply increasing interest in the use of solar energy was and remains the price policy of the oil exporting countries. Perhaps already we shall be grateful —but certainly future generations— that the tripling of oil prices in October 1973 created a shock effect which led to increased efforts to become more independent from energy imports.

The threatening depletion of these oil reserves and the still unclear effects of other energy sources —for instance, nuclear fission— have also led to intensified research and development, among other areas also in the field of solar energy.

When considering the utilization of solar energy, we in the Federal Republic of Germany must take into consideration that solar energy is an unreliable energy source; this fact has, of course, implications for the different techniques and application possibilities of solar energy. In orden to give you a clearer picture of the climatic situation, I would like to make the following preliminary remarks:

The amount of solar energy which falls on the earth's surface is —taken on a yearly average— eighteen-thousand times greater than the annual energy requirement of the earth's inhabitants. In a densely populated and energy intensive country which receives little solar radiation —such as the Federal Republic of Germany— this proportion is reduced to fifty times greater. Nevertheless, even this is a inconceivably large quantity of energy.

Inspite of this, to date a still insurmountable barrier remains for the economically feasible utilization of solar energy: it is the fact that there are large daytime and seasonal variations in solar insolation. Solar energy is an unreliable energy source particularly in our maritime, northern regions.

Compared with an overcast January day, on a sunny June day 50-times the energy (8 as compared with 0.16 kWh/m^2 and day) and 30-times the power (600 as compared with 20 W/m^2) are radiated onto our country. In the first slide (Slide 1), you can see the situation in which our country finds itself as compared with the situation in other countries on the earth.

Slide 14 shows the average number of sunshine hours in our country stated in hours per year. From this slide, you can already make comparisons with your own country. The maximum values are 2000-1900 hours per year.

In the next slide (15), which shows the values for the USA, you can see that the best values reached in the Federal Republic are only as high as the lowest values in the USA.

Furthermore, we must take into consideration the fact that the time period in which solar energy is available does not correspond to that in which a large quantity of energy is needed (2).

For instance, electricity could only be produced in our country during the noonday hours on a few summer days. On a few further reasonably favorable days, this would also be theoretically possible. Thus, this form of solar energy utilization is not a feasible alternative for the Federal Republic.

However, in our country solar energy can play a role in water and space heating when certain technical «tricks» and «indirect methods» are used. The unreliability of the sun as an energy source could be compensated by utilizing large energy storage units or supplementary energy sources. The climatic conditions require that all possibilities for the utilization of solar energy be carefully thought through, also from the scientific perspective. This has already been largely done. Many facilities designed for water and space heating, but also for air-conditioning and generation of electricity, in sunny countries have been constructed; I would like to mention a few examples. Opinions about the degree to which solar energy can satisfy the energy demand in our country —seen both from the technical and economic perspective— remain divided.

I have already mentioned that solar energy does not represent an alternative to nuclear energy for the generation of electricity. It is also understandable that electricity will be necessary for the utilization of solar energy, although, of course, only in small quantities. Thus, those who fight the expansion of the electric generation network also make more difficult the utilization of this inexhaustible energy source.

In a sense, however, solar energy *can* pose an alternative to heating with oil. With respect to the Federal Republic, this represents one of the major opportunities for solar facilities. 60 to 70 % of the energy requirement for industry, trade, agriculture, transportation, and domestic use is heating energy. If one considers only the domestic sector, which will demand the highest proportion of energy in the next decade, this sector uses 90 % of its energy as heating energy. With the increasing scarcity, price, and environmental damage of the high-grade energy sources used until now —energy sources such as natural oil and natural gas— it will be necessary in the future to use these high-grade primary energy sources for high-grade useful energy and less for low-grade useful energy. In this case, valuable oil would no longer be used in such quantities for heating purposes. In the future, it will be more urgently needed for fertilizers, insulation materials, textiles, drugs, synthetics, food-stuffs, construction materials, etc.

For some industrial companies, for the Federal Ministry of Research, and for a steadily growing number of home owners or people interested in building a home, this fact ist clear: heating with the sun has a future.

During about only three years, in our country important companies concerned with electrical and mechanical engineering, with chemistry, with the space program, and with energy technology have launched extensive development programs in all areas of solar technology; this research has been initiated with the support of the Federal Ministry of Research and Technology (BMFT). Sixteen large companies have united their efforts in the Arbeitsgemeinschaft Solarenergie e.V. (ASE — a joint working group for solar energy). The goal of this group is to promote the investigation, testing and development of new possibilities for the use of solar energy. These goals also include joint work on mutually interesting technical projects, dissemination to the public of information on the possibilities for utilizing solar energy, *and promotion of international collaboration.* Based upon the results of basic research, upon the «know-how» which grew out of the technical development, and upon the experience gained during practical use of solar facilities, these companies plan, supply and construct components for solar systems, as well se complete systems. They analyse energy problems and calculate the economic feasibility.

In this area, many research and development projetcs have been furthered by the Federal Ministry of Research and Technology. R & D projects are generally only partially subsidized, in most cases by 50 %. Governmental expenditures for solar energy have risen from 1.5 million DM in 1974 to 6 million DM in 1975 and *12 million DM in 1976*. The financial ceiling foreseen in the program is 14 million DM per year.

As of August 1976, a total of 24 solar energy projects were being subsidized by the Federal Government:

— System studies (15).
— Solar-thermal conversion
- solar houses and demonstration projects (2)
- complete systems (2)
- components.

— Solar-mechanical conversion for electricity generation and water pumping (15).
— Photovoltaic conversion (14).
— Photochemical conversion (1).

A country anticipating the future utilization of solar energy must have the means to measure the solar radiation and related parameters in all of its climatic regions and at potential solar energy utilization sites. Furthermore, the design and evaluation of solar energy systems and components require certain essential solar radiation and weather data. A solar data collecting network will be established consisting of a number of small stations set up in meteorologically typical regions. The instrumentation of the stations set up in meteorologically typical regions. The instrumentation of the stations will be standardized by international co-operation within the International Energy Agency. This data collection project will also be funded by the Federal Government.

The Federal Government does not only give financial support. It also provides opportunities for international cooperation. In this respect it is particularly gratifying that the finalization of a cooperative agreement with *your* country is near at hand. Based upon this agreement, a test center for solar systems will be built in the vicinity of Almería; in the future, German companies will be able to cooperate with Spanish groups in research and development in the area of solar energy utilization.

Ladies and gentlemen, after this general survey, I would now like to turn to individual technical areas related to the use of solar energy. I will only give technical details in a few cases. However, should you desire particular information, I would suggest that you correspond with me. I would be happy to send you the requested information or to bring you in contact with the companies which can be of assistance to you. In this connection I would like to mention that you can obtain a small brochure today which will give you additional information. Now let me begin with the most visible part of a solar system: the collector.

COLLECTORS

Concentrating systems are indispensible in all cases in which high temperatures are necessary (higher than about 130°C). This is, for instance, the case with thermal power generation from solar energy. In principle, the concentrating systems have one characteristic which seriously handicaps them in Central Europe: they are not able to concentrate the diffuse celestial radiation onto the absorber surface. For this reason, the M.A.N. company has devoted its attention to the development of concentrating collectors for use in small solar power stations primarily located in sunny countries.

In this pilot facility (slide 16), cylindrical parabolic mirrors are used. The water which is to be heated flows through a black-coated steel pipe located in the focal line of these mirrors. These collectors can be produced inexpensively, and, depending on the required output, they can be multiplied section by section. The constant realignment of the mirrors in the direction of the sun is carried out electrically by simple solar sensors and mechanical adjustment motors which use only a small percentage of the energy produced. The steam which is produced is stored in an insulated energy storage unit from which the required energy can be extracted at the desired power level, either when it is needed or during the night.

Two different types are being tested as steam engines: a conventional 10 to 100 kW linear-piston steam engine and a new and economical 10-30 kW rotary-piston steam engine according to the screw expansion principle. In the experimental facility, the waste heat of the steam engines is alternatively passed to an absorption unit which provides cooling. The refrigeration unit could air-condition a large house. In the winter, the refrigeration unit can be reversed and used for heating as a heat pump.

Since a large proportion of the electricity produced in the southern countries is used to run air-conditioning units, the absorber-refrigeration units which can use waste heat are particularly significant here. A desalination plant which uses the surplus steam energy could also be linked up to the facility.

This small solar-thermal power plant is being developed for different sizes. Depending on the number of collectors, an output of 15 - 1000 kW will be produced. This slide shows a 50 kW facility with whose output pumps are used to irrigate a desert area and the adjoining work and living quarters are provided with electricity and air-conditioning. Depending on the size of the facility and based upon series production, it is estimated that the cost of electricity from such facilities will be about 10-30 German Pfennige/kWh; thus, at least for remote areas, one can hope for the achievement of economic feasibility.

Since the proportion of diffuse radiation in the global radiation falling upon our country is particularly high the efforts of industry to find applications for solar energy are directed primarily on the development of flat-plate collectors.

In addition to the already «classical» flat-plate collectors, which I do not want to describe further, collectors based on the heat pipe principle and using vacuum technology have been developed.

The difference between the heat pipe collector developed by DORNIER (Slide 3) and the classical collector is in their method of heat transmission. The extruded aluminium profiles, which have a blackened surface, assume the function of the absorber. The pipe on the underside is evacuated and contains a small amount of a readily evaporable fluid; this pipe transports collected heat away from the absorber to a heat exchanger at the top. This system has the advantage that the heat is only transported in one direction.

Furthermore, heat losses from the collector (for instance, at night) are thereby automatically almost totally avoided. In addition, the low heat capacity of the collector enables rapid heating-up.

The ERNO company has developed a vacuum-insulated collector for which the area over and under the absorber surface is almost completely evacuated. Convective heat losses are thereby almost entirely eliminated. A further consequence of this design is that the collector is extremely flat (about 5 cm).

In another design (Slide 4), vacuum insulation is achieved by evacuated glass pipes which are closely aligned next to each other over the absorber surface. This vacuum collector was developed by PHILIPS.

HOT WATER PREPARATION

Ladies and Gentleman, as Slide 2 already showed, the summer season in the Federal Republic is particularly favorable for the utilization of solar energy for heating water. Favorable conversion efficiencies can already be reached with relatively simple collectors, since the collector operates in the low-temperature range for a large proportion of the water which is to be heated; furthermore, the ambient temperature is relatively high during the summer months. Also important when considering the amortization and political economics associated with the use of solar water heating is the fact that conventional oil-fired boilers only operate at a very low efficiency level during the summer. A relatively large quantity of heating oil can be saved when the oil-fired boilers are inactivated and replaced by a few collectors. If oil prices continue to rise, this method of heating water during the summer months will become particularly interesting from the economic perspective.

Based upon the practical experience gained, I would like to give a few details:

The total collector surface area for a 4-person household with higher-than-average hot water consumption is about 6 to 8 m^2; the hot water storage tank should hold between 300 and 600 l. During longer overcast periods —even during the summer— supplementary heating of the water will be necessary. Utilization of the oil-fired boiler for this purpose is not reasonable, since the heat loss from the boiler during the warm-up phase would largely cancel out the useful solar energy contained in the preheated water. During the summer months, electrical energy represents the most suitable form of supplementary energy. The amount of energy needed for supplementary heating is low when the storage tank has been outfitted with an electric heating coil.

During the heating season, the oil-fired boiler represents the most suitable form of supplementary heating, since electricity is a form of line-bound energy and should not be used to take up the energy slack during winter months with low insolation levels.

This slide (5) shows the individual components of such an integrated system:

Collectors, storage tank, oil-fired boiler, heat exchanger for the collector circuit and for the boiler, as well as the electric heating coil for supplementary heating during the summer months.

An experimental facility equipped with 3 m^2 BBC-collectors and a 150 l storage tank; 140 l of hot water are taken daily from the storage tank, a figure which corresponds to the normal daily hot water requirement for two persons.

The next slide (6) gives the energy balance for this experimental facility. When water shall be supplied at a temperature of 45°C, 80 % of the hot water requirement can be supplied by solar energy between May and September; taken on a yearly average, 50 % of the hot water requirement can be covered. These values depend on the overall design of the system, the annual variation in insolation conditions, and above all, on the habits of the hot water users. Since you are «closer to the sun» in your country, you will, of course, achieve substantially better results with such a system.

With respect to the saving in fuel oil, one can say that —depending on the efficiency of the oil-fired boiler, the system design and the habits of the hot water users annual savings of 100 to 200 liters per square meter collector surface area can be achieved. Naturally these savings will be higher in your country. These relatively high savings are possible because of the relatively low summertime efficiency of conventional water heating systems such as oil-fired boilers. The proportion of oil which can be saved during the heating season is very small —about 10 to 15 % of the value given above— since the conventional hot water preparation system operates with high efficiency during this period of low insolation. Thus, solar hot water preparation is particularly interesting from the economic standpoint in those areas, in which fossil-fired heating systems operate with a low degree of efficiency during the summer months.

Space heating

With respect to space heating in our country, we must devote particular attention to developing effective systems appropriate to our climatic conditions. This advanced technology has particular advantages when used in countries receiving more sunshine.

As you can see in this slide (2), the conditions for using solar energy for space heating are not very good in our country; the period in which solar energy is abundantly available does not correspond to the period in which space heating is most required. The insolation during the months from November to February is very low; but about 60 % of the heat demand for space heating occurs during this same period. Long-term storage of excess heat collected by the solar collectors during the summer months for use during the peak heating period will not be feasible for some time to come, since this type of storage is too expensive. Therefore, space heating with collectors will —for the present— be essentially limited to covering the space heat demand during the transitional months. For the most part, this function will be taken over by a conventional heating system during the peak heating period. The prospects for solar space heating, when viewed from the perspective of its economic feasibility, are not as good as they are with solar hot water preparation. For each square meter collector surface, one will achieve lower annual energy savings.

When solar collectors are used for space heating, we must, of low-temperature heating systems is necessary if one wants to utilize the highest proportion of the «collected» solar energy, unless highly efficient collectors are used. Experience to date has shown that a collector surface area of about 0,3 to 0.4 times the actual living surface area which is to be heated would be required to cover the heating demand during the transitional heating season. In order to guarantee a reserve capacity for a few days, we also provide for a storage tank with a water capacity of 5 to 15 m^3, in addition to the solar collectors.

For the period during which solar energy cannot contribute to satisfying the heat demand, a conventional heating system —such as an oil-fired heating system— is the most reasonable alternative.

Solar energy can be further exploited when heat pumps are used.

As long as the storage tank or the collector provides a temperature level adequate for the surface heating system, the heat pump is not taken into operation. When the feed-in temperature to the surface heating system drops below the required level, the heat pump is taken into operation. In this case the solar storage tank is cooled down to 5°C. If the insolation level is so low that even the heat pump can no longer cover the heat demand, the oil-fired boiler is taken into operation.

This system is used in the solar house developed by the DORNIER company an the electric utility company RWE.

The slide (8) shows the mounting of the Dornier heat pipe collectors. To date, the following annual energy balance has been achieved during operation (Slide 9): this annual energy balance shows clearly that with this system 55 % of the energy requirement can be satisfied by solar energy and another 15 % by the electrically operated heat pump. The remaining requirement must be provided by an oil-fired boiler.

One can summarize the results for solar assisted space heating in the Federal Republic as follows:

— if one employs collectors and a heat pump, 55 % of the heat demand can be covered by solar energy; 15 % of the energy demand will be covered by electrical energy, which is required to operate the heat pump. The remaining 30 % is provided by conventional energy sources.
— if only collectors are employed, about 40 % of the heat demand can be covered by solar energy, and the remaining 60 % must be provided by additional energy sources.

In addition to the house which I have just shown you, there are a number of additional solar houses. Some serve research purposes, but others are already equipped with series-produced systems.

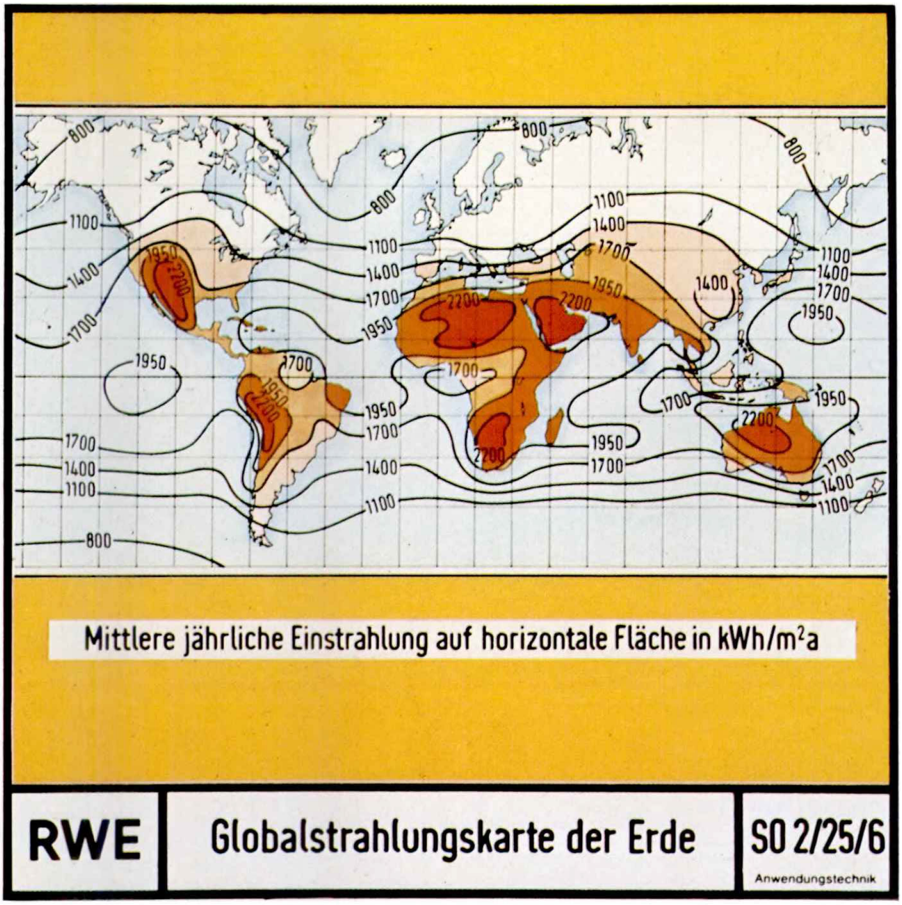
You wil probably be particularly interested to know that, for instance, the companies MBB, BBC and Philips have agreements with companies producing pre-fabricated houses; one can already buy houses from these companies which are equipped with solar systems for heating water. Based upon practical experience gained to date, one can, of course, also buy complete systems for conventionally-built houses. The following slides (10, 17, 19) should give you a preliminary impression of such houses.

THE UTILIZATION OF SOLAR ENERGY IN OPEN-AIR SWIMMING POOLS

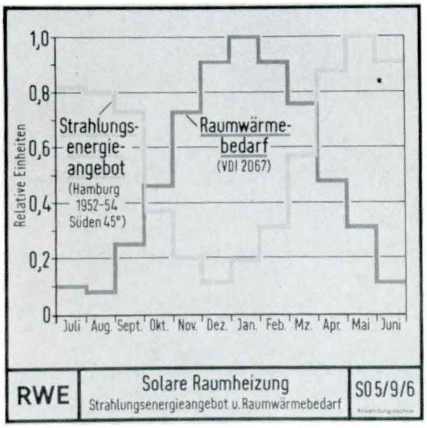
In our country, the use of solar energy for swimming pools is particularly favorable, since the heat demand occurs at the same time as the availability of solar energy. In August 1976, the largest solar facility of this type constructed to date in the Federal Republic was taken into operation. This facility is in Wiehl, a small town in the vicinity of Cologne (Slide 11).

The facility in Wiehl consists of an open-air swimming pool and a multi-purpose hall. The large solar collector array for heating the swimming pool water is located on the roof of the multi-purpose hall. This installation was planned and constructed by the BBC company.

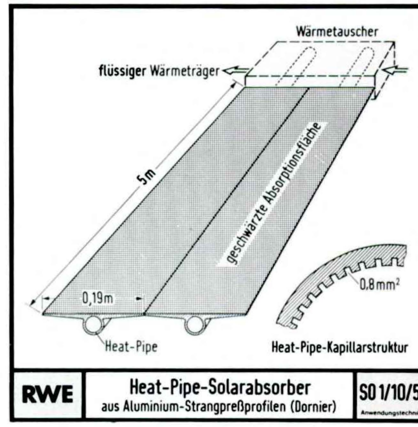
A small solar collector array for heating shower water will be installed on the roof of the warming hall.


Mittlere jährliche Einstrahlung auf horizontale Fläche in kWh/m²a
RWE
Globalstrahlungskarte der Erde
SO 2/25/6
Anwendungstechnik

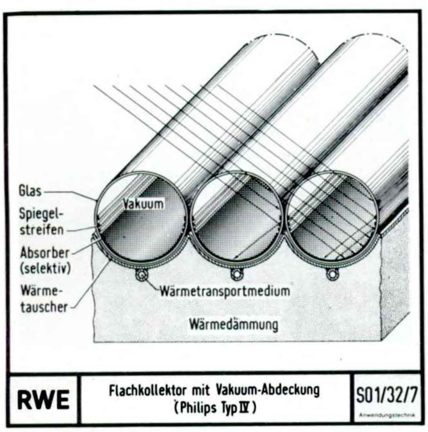
SLIDE 1



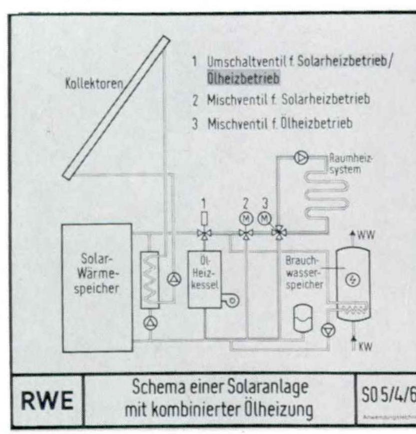
SLIDE 2



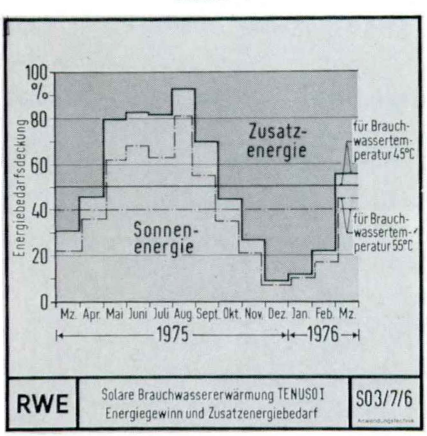
SLIDE 3



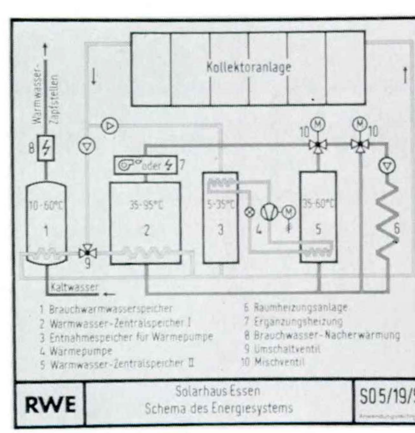
SLIDE 4



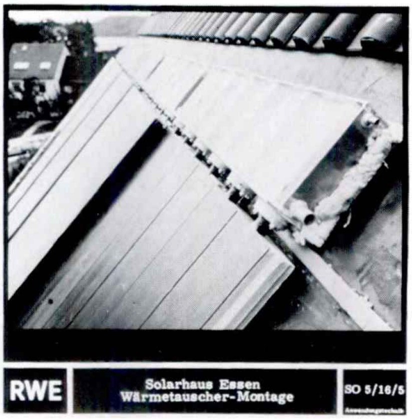
SLIDE 5



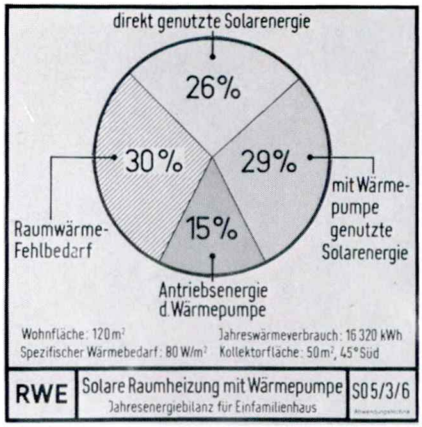
SLIDE 6



SLIDE 7



SLIDE 8



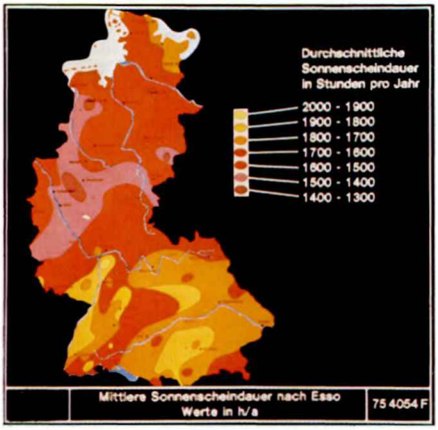
SLIDE 9

SLIDE 10

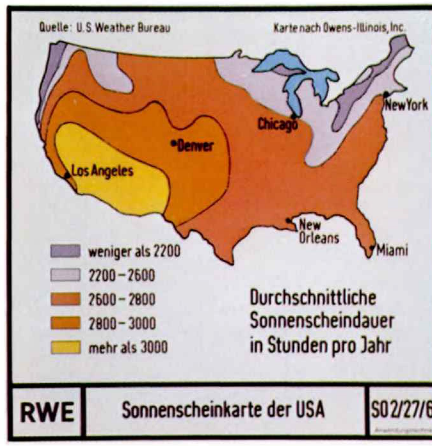
SLIDE 11

SLIDE 12

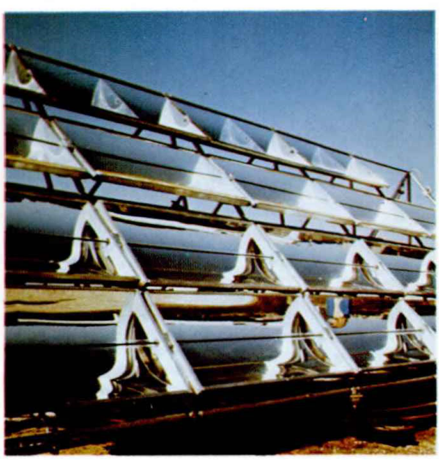
SLIDE 13



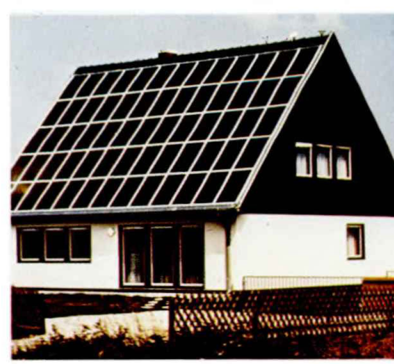
Slide 14



Slide 15



Slide 16



Slide 17

Slide 18

Slide 19

The multi-purpose hall is used as an ice skating ring during the winter. The refrigeration unit which was installed for producing ice and providing heat can also be used for heating the water of the outdoor swimming pool during the summer. This would be necessary when the solar collector system cannot supply sufficient heat due to unfavorable weather conditions. In orden to heat the pool water, the refrigeration unit —which now operates as a heat pump— extracts heat from the ground surrounding the multi-purpose hall.

The open-air swimming pool consists of 4 basins which have a total water surface area of 1460 m^2. The three large basins are equipped with a covering system which will reduce the heat requirement for these basins by 40 to 50 %. In addition, this open-air swimming pool utilizes for the first time a heat recovery system in which heat is extracted from the pool water used to rinse the filters. A 30 % reduction in the energy demand is expected. Finally, the non-swimmers' pool is lined with dark-blue tiles, because these tiles show a high degree of absorptance for global radiation. The heat demand for the non-swimmers' pool is thereby reduced by 50 %. Thus, one can expect a heat demand for the swimming pool at Wiehl which is about on-third the normal level.

The large collector array on the roof of the multi-purpose hall consists of 1100 collectors with about 1500 m^2 absorber surface area (Slide [18, 12]).

The roof sheating of the multi-purpose hall is aluminium. Since the underside of the collectors is also made of aluminium, global radiation is reflected from these surfaces. Part of this reflected radiation strikes the collectors and thus increases its absorption.

One can estimate the efficiency of the collector system installed in Wiehl. During the five-month swimming season, the efficiency is about 55 %. This means that for each square meter absorber surface, 2 kWh of useful energy are collected each day. This high efficiency is due to the fact that the radiant energy is converted into heat in the temperature range of only 26 to 30°C.

In addition to the collectors an earth-heat pump is being used to cover the heat demand of the swimming-pool or the multipurpose hall.

Before I conclude my presentation of the total facility, I would like to make a remark concerning the energy situation: if one takes into consideration that the heat stored in the ground is solar energy, the heat supplied to the open-air swimming pool in Wiehl is largely solar energy. In fact, solar energy in this sense accounts for 90 % of the supplied heat. Electric energy is only required for operating the motors, the regulation equipment, etc.

AIR CONDITIONING

Solar-assisted air conditioning is a particularly sensible application of solar energy. Although air conditioning is not as necessary in the Federal Republic as it is in sunnier countries, realistic concepts have been developed which provide for a combination of heating and cooling. If heat energy is available —for instance, solar energy— absorber systems have an advantage, since they can use heat directly. Calculations have shown that the additional cost for a system combining heating and cooling would not be more than 10 %. On the other hand, this combination extends the number of hours during which this system can be utilized. Since time constraints prevent me from goign into further details here, I would like to mention again that individuals interested in these details are welcome to contact me later.

On the subject of

PHOTOVOLTAIC ENERGY PRODUCTION

I would like to give you just a short overview which will, I hope, give you an introduction into the state-of-the-art in our contry.

Due to their utilization in the space program over the past 10 to 15 years, solar generators were repeatedly able to demonstrate their suitability for producing electricity.

AEG-Telefunken has become a respected manufacturer of reliable and progressive energy systems for the space program through its successful participation in numerous satellite programs, such as the German satellite «AZUR» or the Canadian communications satellite «CTS».

Their high level of technological «know-how» was also shown in the mission of the solar probre «HELIOS», which was launched in December 1974.

Following the development of space applications, projects for terrestrial application have either been realized or begun.

Promising research results are already available today. For instance, AEG has developed a modular generator concept which would allow construction of generators from the watt to the multi-kilowatt range, depending on the number of generator blocks used.

This slide (13) shows the construction of modules for operating a water pump.

Of course, the particular advantages of photovoltaic sistems lies in their independence from infra-structures.

Therefore, possible areas in which such a system in the watt to kW-range could be utilized are measuring stations on land and sea, for instance small weather stations, then facilities for communications engineering and also transportable and stationary radio stations, not to mention signal stations such as beacon signals and light buoys.

Applications in the power range between 1 and 10 kW are larger facilities for communications engineering for instance stationary broadcasting stations and decentralized small radio and television broadcasting stations, as well as in lighthouses, airport lighting and radar facilities. Another application in this range could be electrically self-sufficient single-family dwellings.

Applications in the high power range between 10 and 500 kW could be decentralized radar stations or self-sufficient power stations used for civilian purposes during emergencies.

In the developing countries, such systems could be used to supply electricity for community facilities in small towns, for water pumping stations, for water preparation facilities, and for community receiving stations.

However, before large-scale application can be realized, many technological and economic problems must be solved. The solution of these problems will require long-terme and continuous developmental research.

A preliminary step in this direction was already taken towards the end of last year. Photovoltaic solar generators with large area solar cells could be manufactured of an unconventional silicon base material; the *efficiency level of these cells is 10 % !*

Solar generators of this type offer the possibility that reasonably priced systems can be developed through concentrated developmental research.

This research result provided an excellent and promising technological basis for future contributions to the terrestrial use of solar energy.

This has been an overview of the state-of-the-art from the standpoint of hardware, which is, of course, based on scientific know-how.

In conclusion, I would still like to mention one additional aspect which is also receiving intensive attention and with represents an important concomitant. This is the question of collector capability and international agreement in this sector.

In orden to enable users of collectors to compare the different collector types, a common basis for evaluation is necessary. An important aspect is the objective measurement of thermal output. Based upon criteria developed in the USA, the companies within the ASE have developed a test procedure; this test procedure is presently being tested in many laboratories throughout the world under the auspices of the International Energy Agency and the research program of the European Community.

In addition to these criteria, criteria which will enable evaluation of thermal and mechanical characteristics are also being established. Among other reasons, such criteria are necessary, so that the user can have confidence in this new technology.

Ladies and gentlemen,
the question of energy preparation in our country is not an «either-or» question. The question «oil or solar energy» or «electricity or solar energy» will not be the subject under discussion. On the contrary, multiple systems will be proposed; for instance, «oil as a storable energy source to cover peak-period demand» and «electricity as auxiliary energy for the operation of solar systems».

In my presentation, I could only give an overview of the state of solar energy technology in the Federal Republic. Furthermore, all figures were with reference to our country. Utilization of present systems will thus yield substantially better results in your country. If you should have a particular interest in any of the aspects of my talk, please let me know.