IEA

SOLAR R&D

INTERNATIONAL ENERGY AGENCY

programme
to develop and test
solar heating
and cooling systems

task II
coordination of R&D on solar heating and cooling

compilation of background papers on national solar heating and cooling programs

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COMPILATION OF BACKGROUND PAPERS

ON

NATIONAL SOLAR HEATING AND COOLING PROGRAMS

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1. Introduction

Task II Participants have been exchanging information on their national R&D and D Programs on solar heating and cooling systems and components at the respective Expert Meetings by oral presentation. The background papers compiled in this report were distributed to the Participants together with the oral presentation at the ninth Expert Meeting held in INTA, Madrid in the last October, 1982.

The papers include the information on the national R&D and D programs and also commercialization efforts on solar heating and cooling systems in the respective participating countries. Those who presented the background papers were Austria, Denmark, Japan, Netherlands, Norway and the United States. Belgium, Spain and Sweden have made the oral presentation. Greece and Italy were absent at the Expert Meeting.

Along with the discussions on the Task II business, following topics were covered by the Participants as:

1) Achievements in national solar heating and cooling programs in 1982
2) State of the art and trends in commercialization of solar heating and cooling systems
3) Problems in commercialization of solar heating, cooling and domestic hot water supply systems, and possible breakthrough
4) Technology Transfer
5) Assessment and follow ups in national plan in respective participating countries.

This report might be much more worthwhile by reading together with the working documents of Subtasks A, C and D, Task II IEA, issued in January, 1982.

STATE-OF-THE-ART AND EXPERIENCE WITH SOLAR HEATING SYSTEMS IN AUSTRIA

Gerhard FANINGER [x)]

1. ENERGY SITUATION IN AUSTRIA

Austria is a small industrialized country with some fossil energy resources and long tradition in the use of a specific renewable energy source, hydropower, which still provides about 70 per cent of Austria's electricity supply. In the past decades, however, the significance of Austria's indigenous resource endowment has been steadily eroded. Whereas 25 years ago indigenous sources supplied some 80 per cent of Austria's energy requirement, today the share of net primary energy imports is of the order of 68 per cent and is expected to increase by the end of this decade to some 75 per cent.

Table 1 contains figures on recent developments in the energy supply and consumption of Austria. From 1973 to 1979 the gross domestic energy supply rose by 5,5 per cent, the domestic primary energy supply decreased by 4,0 per cent. However, imports of primary and secondary energy increased strongly (22,9 per cent).

Table 2 further specifies the last column of Table 1. It outlines the changes in the patterns of final energy supply. The shares of gas, electricity, fuelwood and some other sources of energy increased, while those of liquid hydrocarbon-based fuels decreased. Also the heat supplied by district heating systems, included in "other" energy sources, has increased its share in the past years, though it is still rather small.

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Table 1: **Energy supply and consumption 1973 – 1980**

Supply				Consumption		
	in PJ (1 PJ = 10^{15} J)					
Year	Domestic primary energy	Imports of primary and secondary energy	Total [1]	Conversion Input	Conversion Output	Supply to end users [2]
1973	357,536	587,127	903,658	735,085	591,289	703,039
1974	356,050	573,868	891,378	713,908	575,714	696,014
1975	354,691	533,500	867,269	689,740	548,208	668,911
1976	325,180	631,378	905,112	736,351	591,526	711,210
1977	347,271	605,843	872,681	706,610	594,071	695,057
1978	352,535	665,713	906,501	751,455	639,973	718,271
1979	361,426	711,375	947,817	799,480	689,766	765,748
1980	343,383	721,510	943,398	790,609	683,848	761,075

[1]) Domestic gross energy supply after deduction of energy exports and consumption as well as losses and changes in the stocks of energy producers.
[2]) After deduction of non-energetic consumption and taking into consideration the recorded changes in the stocks of energy consumers.

Table 2: **Energy supplied to final users by energy sources 1973 – 1980** (in %)

Year	Solid mineral fuels	Liquid petroleum-based fuels	Gaseous fuels	Electrical energy	Firewood	Other energy sources
1973	13,58	54,49	13,27	13,25	3,68	1,73
1974	14,10	51,86	14,96	13,95	3,56	1,57
1975	13,19	52,43	14,56	14,31	3,69	1,82
1976	12,54	51,00	16,48	14,59	3,52	1,87
1977	11,64	52,18	15,19	15,44	3,66	1,89
1978	11,12	50,89	16,09	15,58	4,15	2,17
1979	12,36	50,57	15,32	15,03	3,68	3,04
1980	11,86	49,26	16,17	15,70	3,90	3,11

Table 3: **Energy consumption by economic sectors** (in %)

Area of consumption	1977	1978	1979
Transport	24,4	23,5	24,0
Residential uses	24,9	26,0	41,7
Other small-scale uses	12,9	13,0	
Industry	37,8	37,5	34,3
Consumption by final users	100,0	100,0	100,0

Table 1 to 3: Energy supply and consumption in Austria

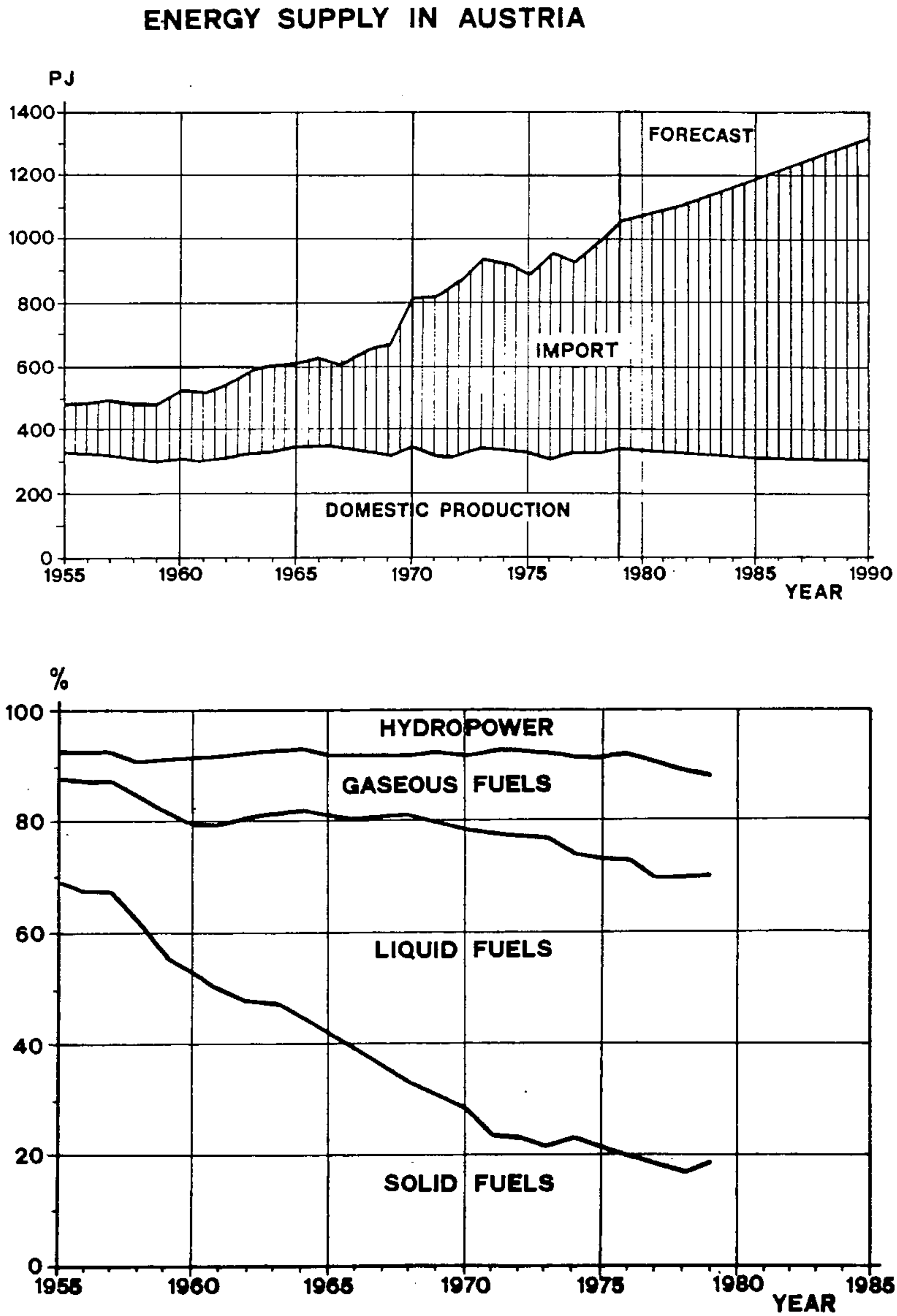

Figure 1: Energy supply and energy sources in Austria

Table 3 indicates the use of energy by areas of consumption. The transport sector's share remained almost constant during the last years. Industry lost some percentage points, while residential and other small-scale users increased their shares.

The value of energy imports (fossil fuels, electricity) amounted to about 25 billion Austrian Schillings AS*) in 1978 and about AS 33 billion in 1979. The value of energy exports (mainly the balance of electricity exports and imports) amounted to AS 2,8 billion in 1978 and AS 3 billion in 1979. Net imports of fossil fuels and energy caused an energy trade deficit of AS 30 billion in 1979 and about AS 45 billion in 1980.

The deficit is largely the effect of increasing energy prices. In 1979, for instance, energy imports, quantitatively, were 29,5 per cent higher than in 1972. Their value, however, had risen by 289,9 per cent. In the same period, the energy trade deficit rose by 347,7 per cent, i. e. from AS 6,78 billion to AS 30,35 billion.

The energy imports, mostly in form of liquid hydrocarbons, impose a heavy burden on Austria's balance of payments and supply security. Thus, Austria's energy policy emphasises, above all, the need for lessening the dependence on liquid hydrocarbons. In order to achieve this goal, a substantial effort in energy planning and research must be undertaken. This effort will have to focus on the

- optimal exploration and exploitation of indigenous energy resources;
- efficient and rational use of energy;

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*) 1 US dollar = AS 17,20 (June 1981)

- identification of adequate substitutes for liquid hydrocarbons;
- diversification of sources;
- assessment of the potential contribution of new and renewable sources of energy;
- development, testing and introduction of new, economically and environmentally sound energy technologies.

2. GOALS AND PRINCIPLES OF ENERGY POLICY AND RESEARCH

To secure Austria's energy supply and to minimize negative impacts on the economy and on the environment, the energy policy and research in Austria are aimed at

- optimizing the exploration for and the use of domestic resources of energy, in particular by further exploitation of hydropower, and new sources of energy or those rarely used up to now, such as biomass, solar and geothermal energy;
- substituting hydrocarbons as far as possible;
- reducing energy consumption through more efficient energy use;
- securing the necessary energy imports by diversifying supplier countries and energy sources.

The energy policy of the Federal Government emphasizes the exploration for oil, natural gas and coal deposits, and in particular the expansion of both large- and small-scale hydropower. The power plant expansion programme provides for the continuous expansion of hydropower. Besides the construction of large- and medium-size plants, particular attention is given to the expansion of small hydropower plants. As such small plants have considerable potential for future energy supply, a number of measures have been taken for their promotion, such as tax reductions, loans and interst allowances.

These, and other actions, are part of the "package" of measures approved by the Federal Government in July 1979 and supplemented by a timetable. Later a comprehensive and further improved catalogue of measures has been published in the 1980 Federal Government report on energy policy and adopted by the Austrian National Assembly.

The objective of the Austrian Concept of Energy Research is to ensure that work sponsored from public funds is in conformity with the goals of Austria's energy policy and takes into consideration concerns of the economic and research policy, including environmental factors. Austria's Concept of Energy Research was first established in 1974 and is updated periodically.

As founding member of the International Energy Agency (IEA), Austria has accepted responsibility for promoting energy policy and research in accordance with other IEA member countries. Austria's Concept of Energy Research was reviewed in 1980 in the light of the energy, research, development and demonstration strategies presented by the IEA in early 1980.

The Industrial Research Promotion Fund has increased its allocations for energy research in industry from AS 38,35 million in 1977 to AS 114,10 million in 1980. In addition, industry used AS 222,17 million of its research budget for energy in 1980.

In addition to financial support, appropriate legislative measures are often required to accomplish the objectives of research programmes.

The exploration and use of new and renewable sources of energy may create some new legal problems as well. From the point of view of civil and public law, a recently conducted study examined controversial situations arising in connection with the application of commercialized solar and wind energy devices. Possible solutions were elaborated and proposals for new regulations made.

3. METEOROLOGICAL CONDITIONS

In Austria the insolation values vary as follows: March to May 450 kWh/m^2, June to August 520 kWh/m^2, September to November 250 kWh/m^2, December to February up to 160 kWh/m^2. The annual global radiation sum is of the order of 1.400 kWh/m^2; figure 2.

The unfavourable ratio of maximum (June) and minimum (December) irradiation in Austria is obvious. Ratios of 8 : 1 are possible. In the case of certain applications, such as space heating, energy demand is thus highest when supply is lowest and vice versa.

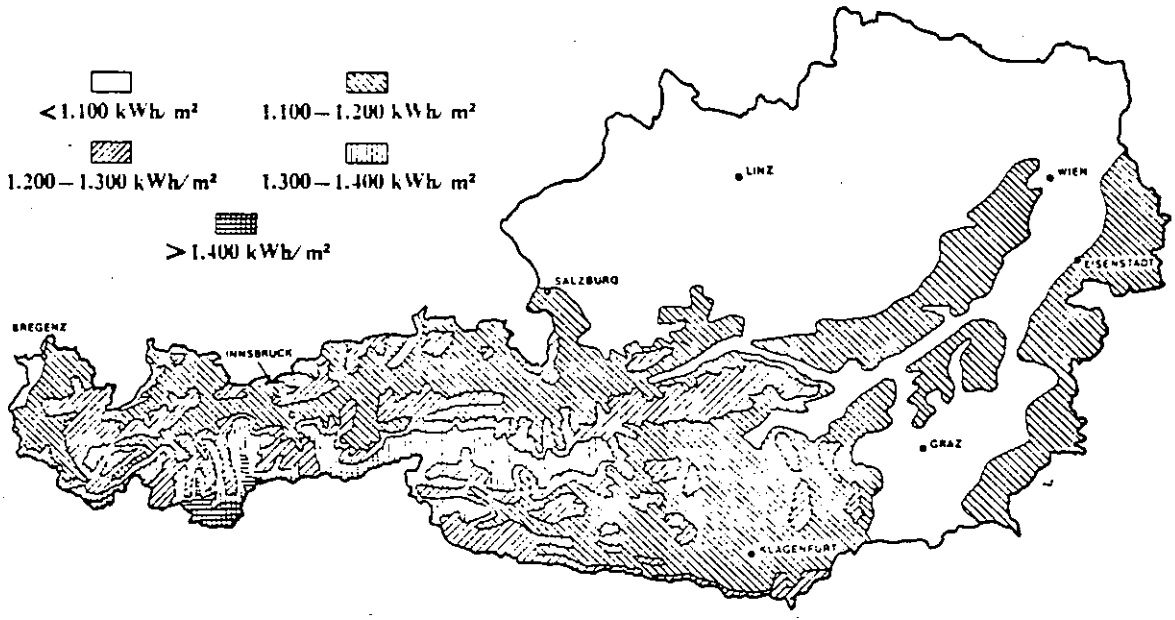
The daily sums of insolation on cloudless days in summer may be as high as 8 kWh/m^{2}d.

The daily variations of insolation, again on cloudless days, are highly dependent on the seasonal cycle. In summer, the maxima attain some 0,9 kW/m^2, in spring some 0,6 kW/m^2 and in winter some 0,25 kW/m^2. During the summer half year, an average 45 per cent of total insolation is diffuse radiation (winter half year about 65 per cent).

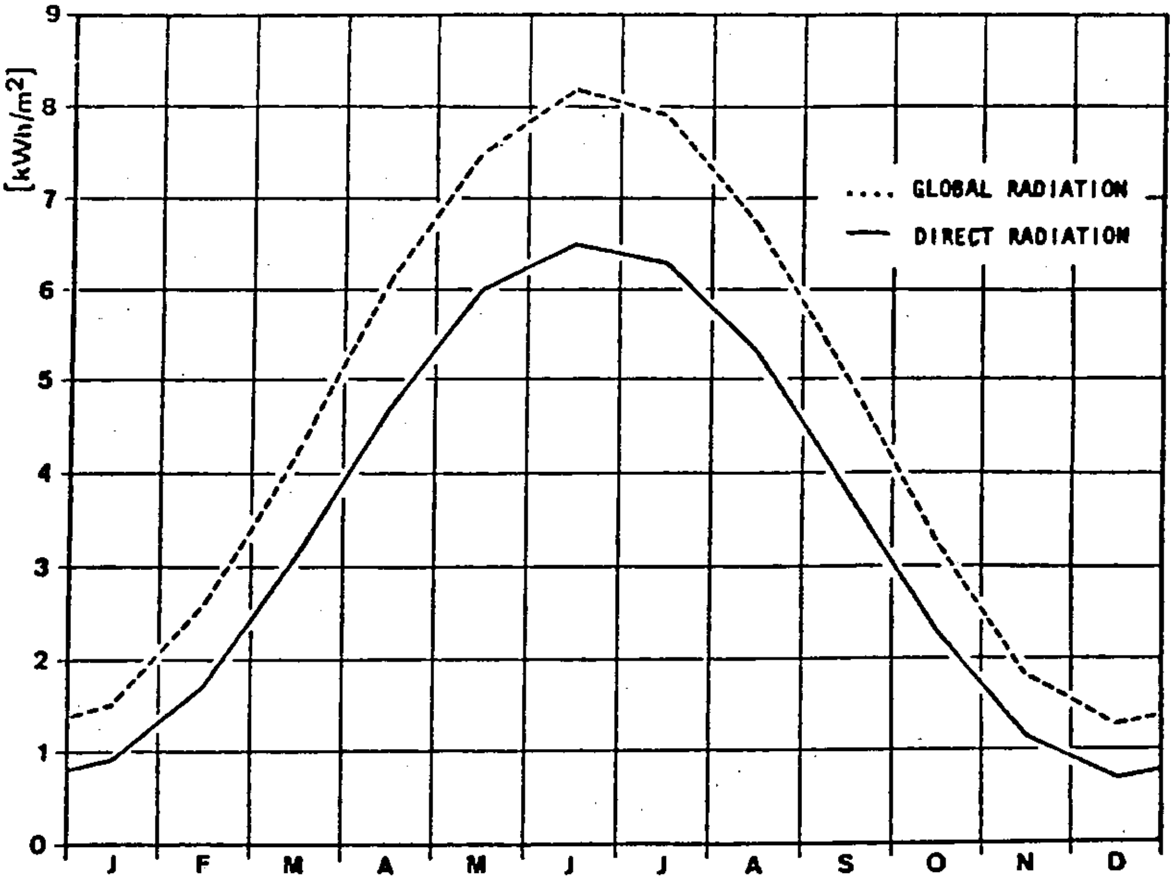
Large amount of heat is stored, although at temperatures below the level needed for practical use, in the environment (ambient heat). The soil temperature 2 meters below surface is + 4 $^{\circ}$C to + 12 $^{\circ}$C, the temperature of surface water (rivers and lakes) may reach + 20 $^{\circ}$C. Ground water has a more or less constant temperature of + 8 $^{\circ}$C to + 12 $^{\circ}$C throughout the year. The temperature of the air varies, of course, more strongly (mean daily temperatures at 200 meters altitude between - 8 $^{\circ}$C and + 20 $^{\circ}$C).

4. EXPERIENCE WITH SOLAR HEATING SYSTEMS

Solar energy can be used for the production of low-temperature heat (up to 50 $^{\circ}$C) by



a) Mean yearly global radiation sums on horizontal surface in Austria



b) Variation of daily sums of global and direct radiation on cloudless days in Austria

Figure 2: Meteorological conditions in Austria

- direct conversion of solar energy into heat through collectors: SOLAR SYSTEMS
- utilization of the solar energy "stored" in the environment in the form of heat ("ambient heat") by means of heat pumps: HEAT PUMP SYSTEMS; Figure 3.

Under Austrian meteorological conditions the flat-plate collector is applicable as it can also absorb diffuse radiation. In order to improve the thermal efficiency by reducing heat losses due to thermal radiation and convection, transparent covers (glass or plastic) are placed on the collectors.

Collectors with transparent covers can be used for residential water heating throughout the year. During the summer months, even plastic collectors can be used.

In combination with heat pumps, non-covered collectors can use other sources of environmental energy, such as the latent heat contained in the condensation water of the air. Accordingly, those collectors performe the additional function of heat exchangers for energy sources contained in the air and they can most likely be successfully used in conjunction with heat pump systems.

At present, solar systems in Austria are used mainly for residential water heating as well as for swimming-pool heating and the combination thereof. In the case of space heating by means of solar and/or heat pump systems, high demands are placed upon the heat insulation of the building and the heat distribution system (low-temperature heating system). Several concepts are being tested at present, with special attention given to their cost-effectiveness.

The thermal energy output of a solar system depends to a large extent on insolation, ambient air temperature and the working

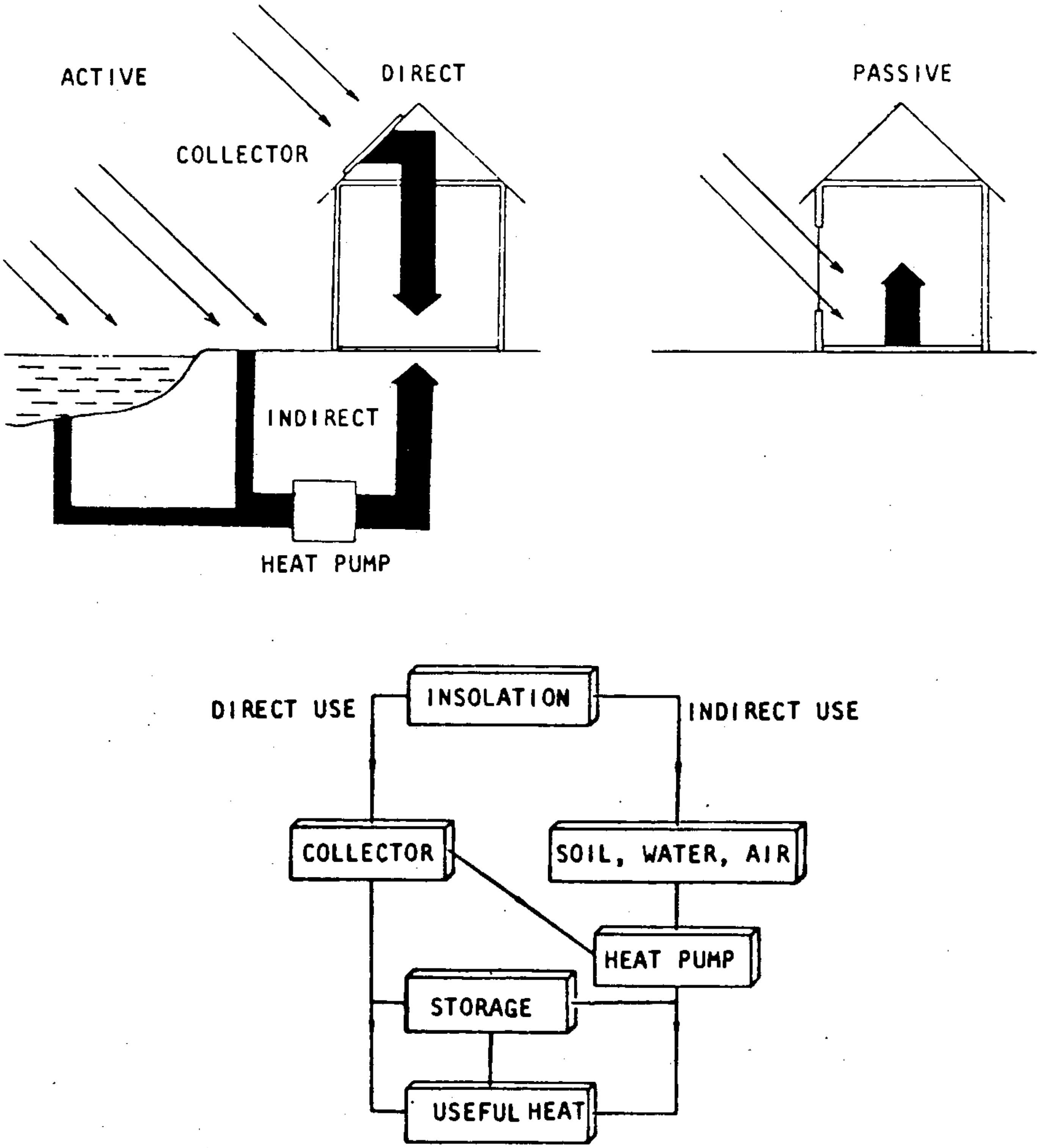


Figure 3: Solar systems for space heating

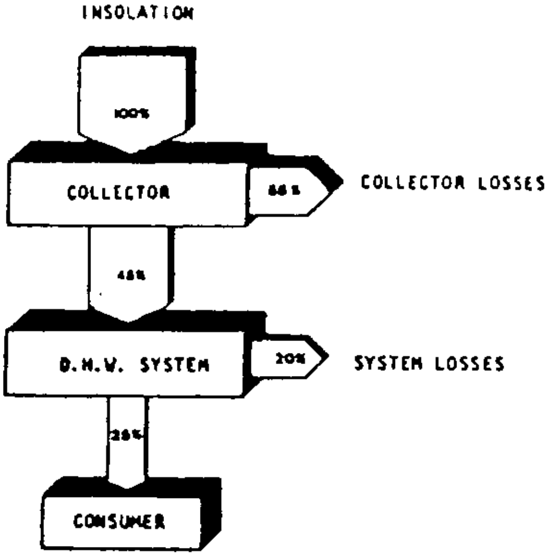
temperature of the collector system. The latter will always be kept as low as possible, i. e. in the case of swimming-pool below 30 °C and in the case of residential water heating below 50 °C. Under these conditions, about 25 to 30 per cent of incident solar energy can be converted into useful energy. Thus about 300 to 350 kWh of the total incident radiation of 900 to 1.400 kWh per square meter of collector area and year can be used in the form of low-temperature heat (300 to 350 kWh/m^2a); Table 4. These figures are confirmed by measurements taken at Austrian solar energy test stations operated on behalf of the Austrian Federal Ministry for Science and Research; Figure 4.

The conventional energy savings resulting from the use of solar heating systems can be determined by the so-called "energy analysis" where all energy inputs and outputs are calculated. Energy input comprises the energy needed for the manufacture of the equipment and the plant itself, as well as the energy required for transport. Energy output (low-temperature heat) depends on the thermal efficiency of a collector, which, in turn, can be determined by using the conversion factor and the heat loss factor of a collector. The "energetic" amortization period for a solar collector manufactured and used in Austria is calculated at 2 to 4 years; Figure 5.

The heat pump makes use of the heat stored in the environment (e. g. ground water, air, soil) and of various waste waters. Its use reduces the primary energy requirements for heat production and lessens the dependence on liquid hydrocarbons.

High-quality energy (electricity, diesel fuel, natural gas) is required for the operation of heat pumps. The conservation of primary energy by using heat pumps for heat production depends on

- conversion losses in the process of the production of energy required for the operation of the heat pump (electricity, diesel fuel, natural gas);

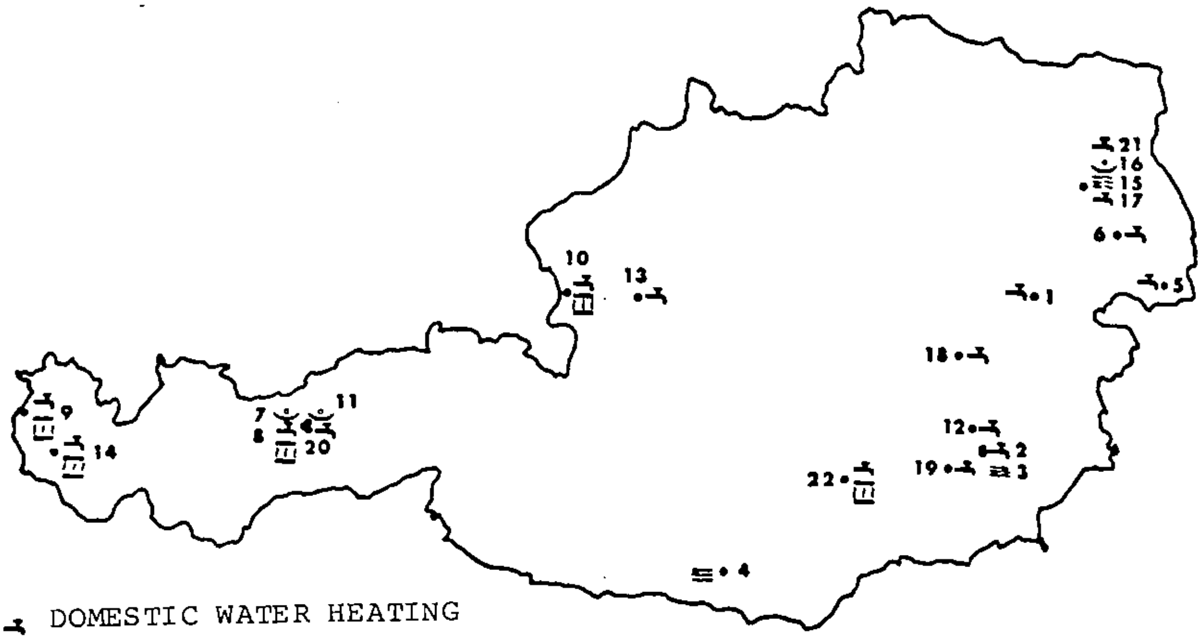


GLOBAL RADIATION

MONTH	HORIZONTAL SURFACE kWh/m²	COLLECTOR SURFACE SOUTH FACING INCLI-NATION: 40 ° kWh/m²	NET-HEAT-OUTPUT	
			kWh/m²	% OF INSOLATION
JANUARY	25,2	35,78	4 bis 7	11,2 bis 19,6
FEBRUARY	43,0	54,61	9 bis 12	16,5 bis 22,0
MARCH	81,4	95,24	19 bis 21	20,0 bis 22,1
APRIL	118,9	126,03	27 bis 31	21,4 bis 24,6
MAY	149,8	146,80	36 bis 44	24,5 bis 30,0
JUNE	160,7	152,67	41 bis 50	27,0 bis 32,8
JULY	164,9	158,30	47 bis 55	29,7 bis 34,7
AUGUST	139,7	143,89	36 bis 43	25,0 bis 29,9
SEPTEMBER	100,6	117,70	29 bis 32	24,6 bis 27,2
OCTOBER	59,8	78,94	17 bis 20	21,5 bis 25,3
NOVEMBER	26,3	37,87	6 bis 8	15,8 bis 21,1
DECEMBER	19,9	29,05	3 bis 5	10,3 bis 17,1
TOTAL	1.090,0	1.176,89	274 bis 328	23,3 bis 27,9

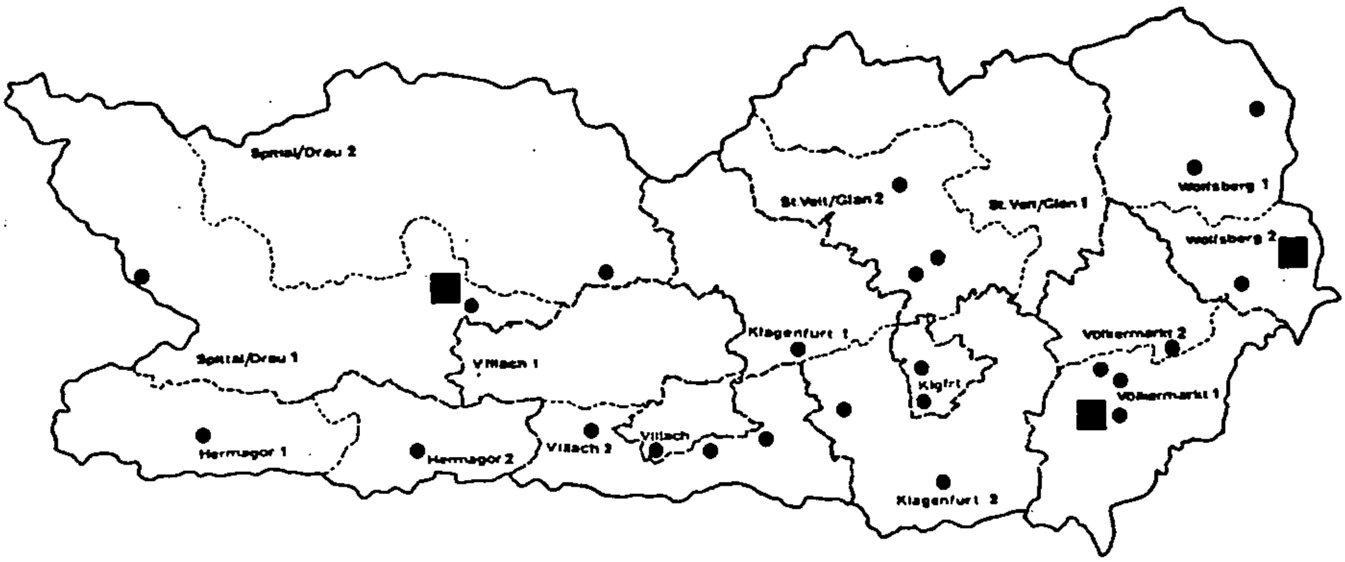
NET-HEAT-OUTPUT OF A SOLAR D. H. W. SYSTEM
MIN. OUTPUT FOR 50 °C HOT WATER TEMPERATURE
MAX. OUTPUT FOR 40 °C HOT WATER TEMPERATURE

TABLE 4: ENERGY-FLOW-DIAGRAM AND NET-HEAT-OUTPUT FOR SOLAR DOMESTIC HOT WATER SYSTEMS IN AUSTRIA



DOMESTIC WATER HEATING
SWIMMING POOL HEATING
SPACE HEATING
COLLECTOR TEST FACILITY

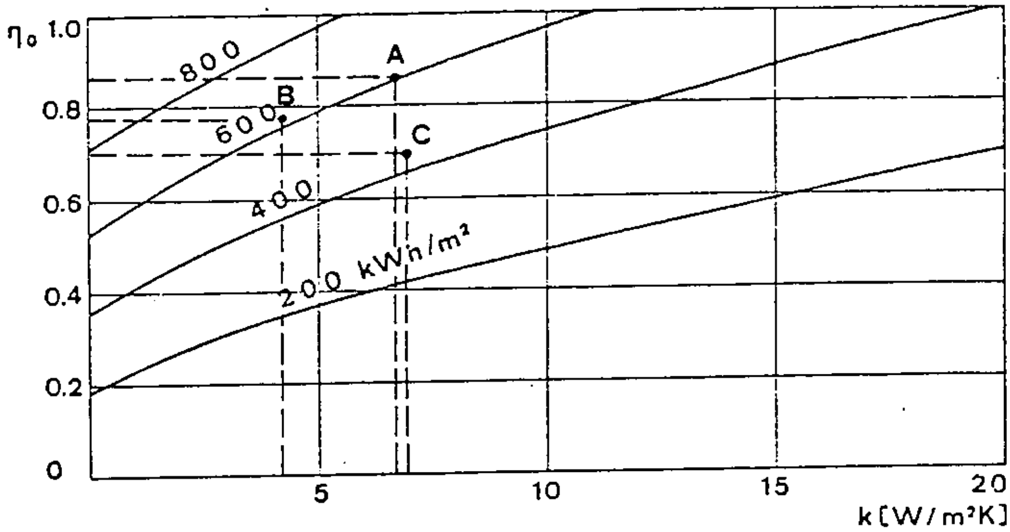
TESTSTATIONS FOR SOLAR SYSTEMS IN THE FEDERAL PROVINCE CARINTHIA



MODEST HOUSES
TOURIST CENTERS AND HOTELS

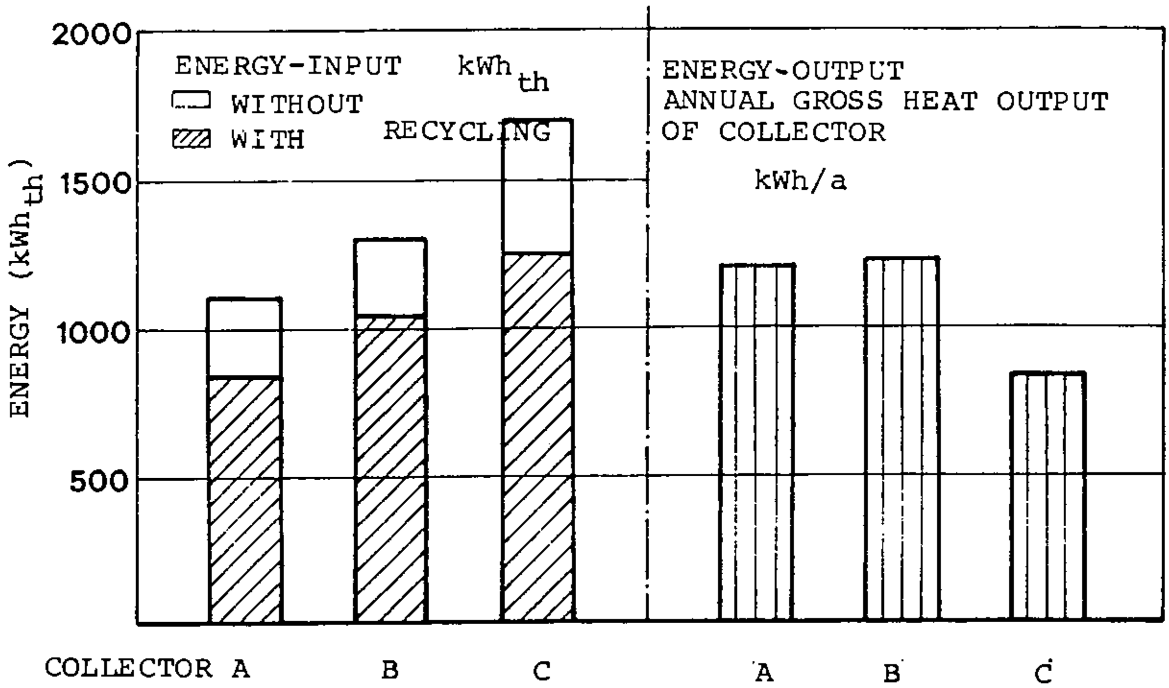
Figure 4: The Austrian measuring network for the practical use of solar energy

STANDARDISED ANNUAL GROSS HEAT OUTPUT OF FLAT-PLATE COLLECTORS



HEAT LOSS COEFFICIENT u W/m^2K

LOCATION: VIENNA
COLLECTOR WORKING TEMPERATURE: 4o °C
AZIMUTH: O ° INCLINATION: 45 °
COLLECTOR AREA: 2 m^2



COLLECTOR TYP	ABSORBER	FRAME	η_o	(k)(W/m^2K)
A	Cu-PLATE Cu-TUBES	Al	o,85	6,7
B	STEEL ROLLBOND	Al	o,78	4,3
C	Al-PLATE Cu-TUBES	Al	o,7o	7,o

Figure 5: Energy analysis of flat-plate collectors

- the coefficient of performance (COP) of the heat pump.

The COP (which has to be higher than 1) will determine the energy saved by an electrically-operated heat pump compared to electric heating (direct heating, boiler heating). If compared to an oil- and gas-fired central heating system, the COP would have to be at least 2. The average COP of heat pumps is of the order of 2,3 to 3,3. The fact that in Austria part of the electricity is generated by hydropower plants even during the winter months facilitate the saving of primary energy by using electrically operated heat pumps; Figure 6.

Gas- or diesel oil-operated heat pumps can save even more primary energy than electrically operated heat pumps as they can utilize also the energy contained in the cooling water of the engine and in the exhaust heat.

The application of heat pumps for space heating is being examined both in demonstrations and practice. Only in particularly favourable cases will it be possible to use groundwater as source of heat, especially as possible negative effects on the recovery of drinking water have to be taken into account. In Austria, the use of ground- or surface-water requires official authorization.

For heat pumps the loamy, hydrous soil is a good heat-extraction medium. It can be heated up, if necessary (in layers more than 2 meters below surface), by solar collectors or waste heat from space and residential water heating.

The use of solar and heat pump systems is increasing in Austria. Until the end of 1980, about 64.000 m^2 of collector area were installed, 62 per cent of which for residential water heating, 18 per cent for swimming-pool heating and 18 per cent in combined systems (residential water and swimming-pool heating). At present, only about 2 per cent of the solar systems are used for space heating; Table 5.

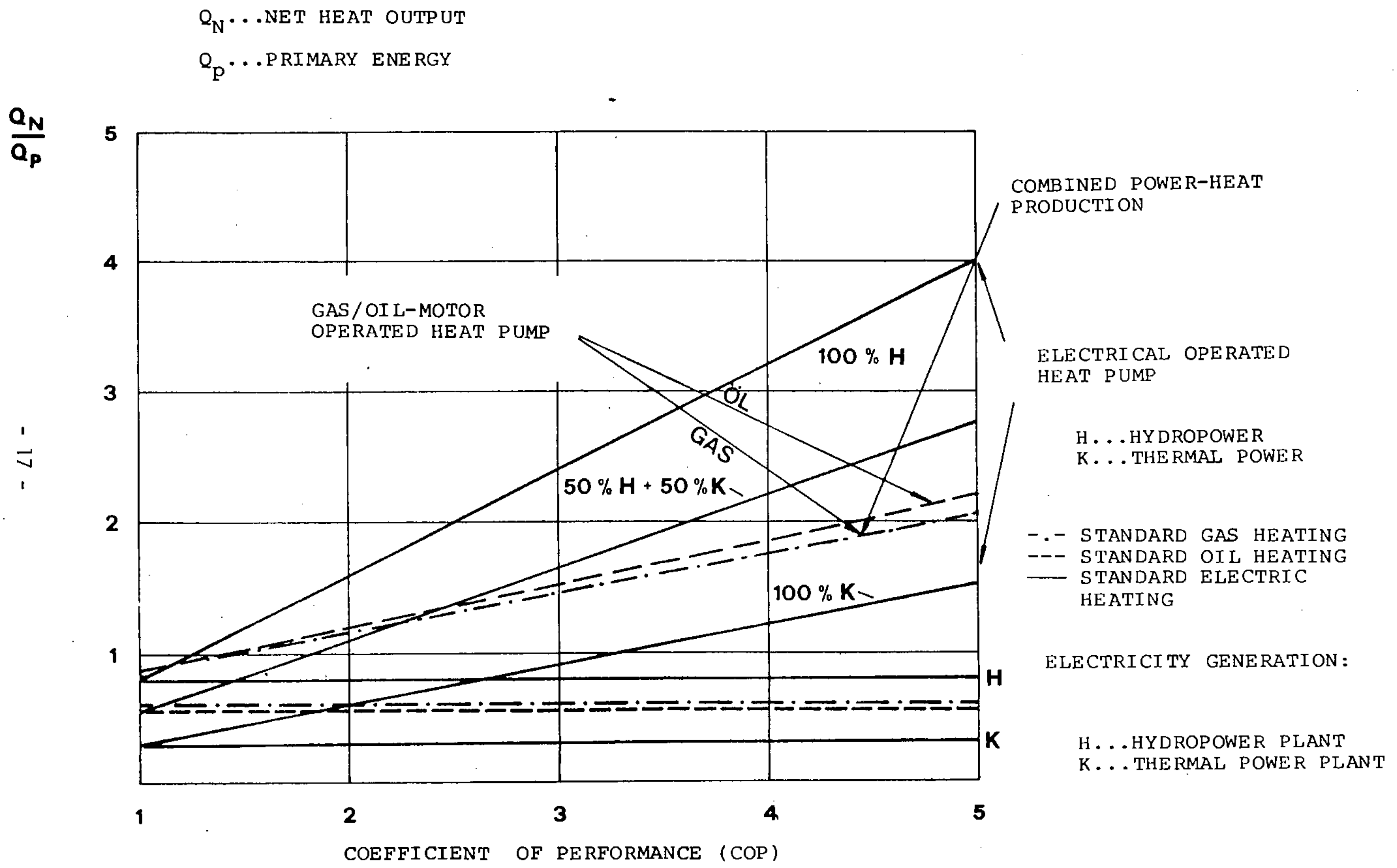


Figure 6: Energy saving with various heating systems

SOLAR SYSTEMS						
COLLECTOR PRODUCTION	56.900 m²	(1980)				
EXPORT	36.400 m²	(1980)				
IMPORT	2.600 m²	(1980)				

INSTALLED SOLAR SYSTEMS 1980	AUSTRIA	EXPORT
DOMESTIC WATER HEATING (DH)	850	1.970
SWIMMING POOL HEATING (SH)	240	530
COMBINATION SH + DH	250	530
SPACE HEATING	30	—
TOTAL	1.370	3.030

INSTALLED COLLECTOR AREA IN AUSTRIA						
YEAR	1975	1976	1977	1978	1979	1980
m²/year	100	2.200	3.500	7.000	27.800	23.100
TOTAL m²	100	2.300	5.800	12.800	40.600	63.700

APPLICATIONS	1975 — 1979	1980
DOMESTIC WATER HEATING (DH)	43%	62%
SWIMMING-POOL HEATING (SH)	36%	18%
COMBINATION SH + DH	18%	18%
SPACE HEATING	3%	2%

DISTRIBUTION OF SYSTEMS BY COLLECTOR AREA	1975 — 1979	1980
< 10 m²	24%	48%
10 to 30 m²	57%	32%
30 to 70 m²	13%	13%
> 70 m²	6%	7%

HEAT PUMP SYSTEMS	
HEAT PUMP PRODUCTION (1980)	8.100
EXPORT	3.500 (43%)

INSTALLED HEAT PUMP-SYSTEMS						
	1975	1976	1977	1978	1979	1980
YEAR	10	30	60	300	800	4.600
TOTAL	10	40	100	400	1.200	5.800

APPLICATIONS:		
	DOMESTIC WATER HEATING	55%
	SWIMMING-POOL HEATING	5%
	SPACE HEATING	30%
	COMBINATION	10%

DISTRIBUTION OF SYSTEMS BY HEAT SOURCES	
AIR	80%
WATER	19%
GROUND	1%

DISTRIBUTION OF SYSTEMS BY THERMAL POWER OUTPUT				
< 3 kW	3 — 7 kW	7 — 15 kW	15 — 30 kW	> 30 kW
42%	13%	21%	17%	7%

Table 5: Solar and heat pump systems in Austria.

By the end of 1980, 5.800 electrically operated heat pump systems were in operation, 73 per cent of which with a thermal power capacity of up to 15 kW. Gas- or diesel-operated heat pumps with capacities over 50 kW are only used in pilot systems.

Some figures may illustrate the increasing manufacturing capacity of the Austrian solar industry. At present, about 56.900 m^2 collector area are produced in Austria annually, 64 per cent of which are exported. 8.100 heat pumps were manufactured in 1980.

Solar systems for the production of low-temperature heat use solar energy directly, i. e. solar energy is converted into heat in the collector and from there supplied to the consumer. Heat pumps in contrast use solar heat stored in the environment which is re-heated by solar energy. Thus, the use of solar energy and ambient heat can reduce the demand for commercial energy (oil, gas, electricity) in particular in the area of space heating. Furthermore, solar energy can be used by the introduction of "passive" solar systems.

It is estimated that 3 to 5 per cent of total primary energy demand in Austria can be saved up to the year 2000, if the application of solar and heat pump technologies further increases. Statistically, the reduced consumption of commercial energy is indicative of the contribution of solar energy (including "passive" solar energy systems and the use of ambient heat) to the energy supply.

5. SPECIAL MEASURES FOR THE PROMOTION OF SOLAR AND HEAT PUMP TECHNOLOGIES

If their application meets specific energy policy requirements, solar and heat pump systems qualify for tax advantages as energy saving investments.

Even under the meteorological conditions of Austria, appropriately designed solar and heat pump systems can reduce the demand for conventional energy (e. g. oil, gas, coal, electricity). This has been demonstrated by examination of selected plants and by the experience gained since 1974 with solar and heat pump systems operated within the framework of the "Austrian Measuring Network for the Practical Use of Solar Energy".

Standards for solar collectors and heat pumps are already available in Austria. Guidelines and recommendations for planning, design and operation of solar and heat pump systems have been elaborated by the Austrian Solar and Space Agency (ASSA) based on results gained with existing facilities.

Reliability, cost-effectiveness, serial production of parts and components and better information on technologies are the preconditions of use of new and renewable sources of energy. Appropriate documentation, teaching and demonstration materials have been elaborated in Austria, in order to provide information to all interested and to promote the use of solar systems, heat pumps etc.

The introduction of new technologies requires good training of technical manpower. For this purpose, seminars are held in regular intervals, dealing with the planning, design and operation of solar and heat pump systems. Between 1977 and 1980 more than 130 seminars were held in Austria on this subject.

EXPERIENCES WITH SOLAR COUPLED STORAGES WITH HEAT PUMPS FOR SPACE HEATING IN AUSTRIA

by Herbert Rünzler [1] and Gerhard Faninger [2]

1. METEOROLOGICAL CONDITIONS AND POTENTIAL FOR SOLAR ENERGY UTILIZATION

In Austria the insolation values vary as follows: March to May up to 450 kWh/m^2, June to August 520 kWh/m^2, September to November 250 kWh/m^2 and December to February up to 160 kWh/m^2. The annual global radiation sum is of the order of 1000 to 1400 kWh/m^2; figure 1.

The daily sums of insolation on cloudless days in the summer period may be as high as 8 kWh/m^2d.

The daily variations of insolation on cloudless days are highly dependent on the seasonal cycle. In summer, the maximum attains some 0.9 kW/m^2, in spring some 0.6 kW/m^2 and in winter some 0.25 kW/m^2.

During the period from May to September, an average of 45 per cent of total insolation is diffuse radiation, from October to April about 65 per cent.

The unfavourable ratio of maximum (June) and minimum (December) irradiation in Austria is obvious. Ratios of 8:1 are possible. In the case of space heating, energy demand is thus highest when supply is lowest.

A large amount of heat is stored in the environment as "ambient heat", although at temperatures below the level needed for practical use. The soil temperature down to two meters below surface is between +4 ^{o}C and +12 ^{o}C, the temperature of surface water (rivers and lakes) may reach + 20 ^{o}C. Ground water has a more or less constant temperature of between +8 ^{o}C to +12 ^{o}C throughout the year. The temperature of the air shows, of course, a greater variation: mean daily temperatures at 200 meters altitude between -8 ^{o}C and +20 ^{o}C.

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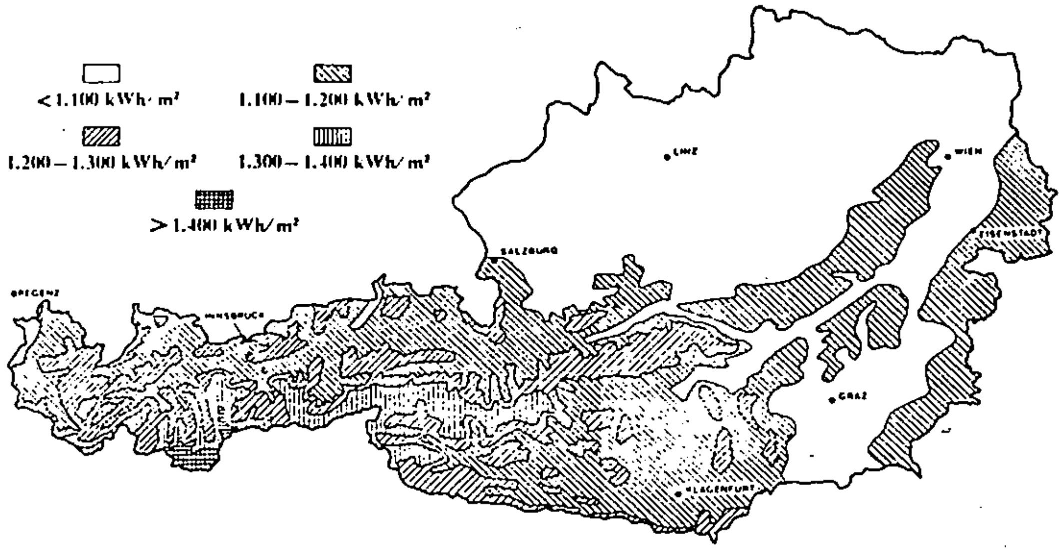
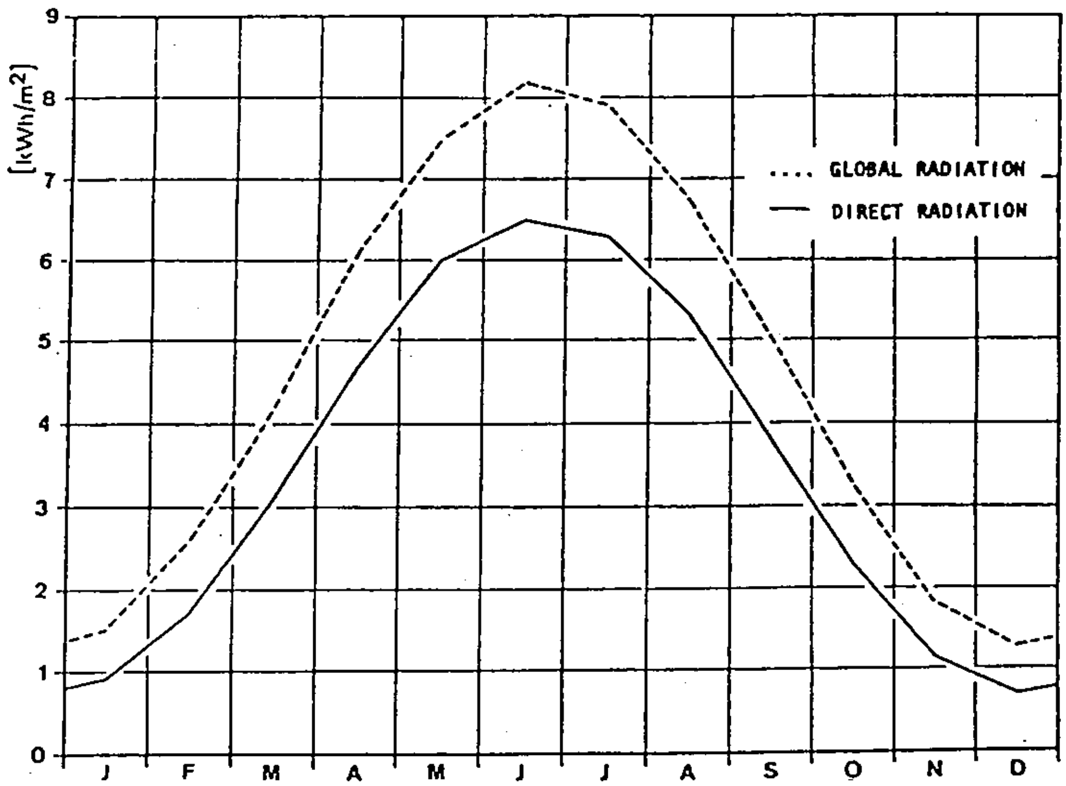


a) Mean yearly global radiation sums on horizontal surface in Austria



b) Variation of daily sums of global and direct radiation on cloudless days in Austria

FIGURE 1: METEOROLOGICAL CONDITIONS IN AUSTRIA

2. SOLAR ENERGY APPLICATIONS AND MARKET PENETRATION

At present, solar systems in Austria are used mainly for domestic water heating, for swimming-pool heating and the combination thereof. Collectors with transparent (glass or plastic) covers can be used for domestic water heating throughout the year. Plastic collectors even without transparent covers can be used for swimming-pool heating during the summer period.

The use of solar systems is increasing in Austria. Until the end of 1981 about 100,000 m^2 of collector area were installed, 60 per cent of which is being used for domestic water heating, 30 per cent for swimming-pool heating and 10 per cent in combined systems; figure 2. At present, only few solar systems are used for space heating, and if, mostly in combination with heat pumps.

At the present state of technology, the direct utilization of solar energy for space heating is not yet economical in Austria. Theoretical examinations have shown that collector areas up to 100 m^2 and a storage volume (water storage) up to 200 m^3 would be required for the space heating of a modest house with 15 kW load. Even with a seasonal hot water storage the heat demand of the house could not be covered.

Heat pump heating systems are being increasingly used for space heating, with air, water or soil as the sources of heat. By the end of 1981, about 12,000 heat pump systems were installed in Austria, of which 50 per cent are used for domestic water heating, 40 per cent for space heating and the remaining 10 per cent for swimming-pool heating and combined systems for heat production; figure 2.

FIGURE 2: SOLAR AND HEAT PUMP SYSTEMS IN AUSTRIA

SOLAR SYSTEMS

INSTALLED COLLECTOR AREA IN AUSTRIA

YEAR	1975	1976	1977	1978	1979	1980	1981
m^2/year	100	2200	3500	7000	27800	23100	31500
TOTAL m^2	100	2300	5800	12800	40600	63700	95200

APPLICATIONS	1975 - 1979	1980	1981
DOMESTIC WATER HEATING (DH)	43 %	62 %	60 %
SWIMMING-POOL HEATING (SH)	36 %	18 %	29 %
COMBINATION SH + DH	18 %	18 %	9 %
OTHERS	3 %	2 %	2 %

DISTRIBUTION OF SYSTEMS BY COLLECTOR AREA

	1975 - 1979	1980	1981
<10 m^2	24 %	48 %	58 %
10 to 30 m^2	57 %	32 %	32 %
30 to 70 m^2	13 %	13 %	6 %
>70 m^2	6 %	7 %	4 %

HEAT PUMP SYSTEMS

INSTALLED HEAT PUMP-SYSTEMS

	1975	1976	1977	1978	1979	1980	1981
YEAR	10	30	60	300	800	4600	5600
TOTAL	10	40	100	400	1200	5800	11400

APPLICATIONS:	1980	1981
DOMESTIC WATER HEATING	55 %	47 %
SWIMMING-POOL HEATING	5 %	6 %
SPACE HEATING	30 %	35 %
COMBINATION	10 %	12 %

DISTRIBUTION OF SYSTEMS BY HEAT SOURCES

	1980	1981
AIR	80 %	79 %
WATER	19 %	17 %
GROUND/ABSORBER	1 %	4 %

3. RESULTS OF RESEARCH, DEVELOPMENT AND DEMONSTRATION IN THE FIELD OF SOLAR AND HEAT PUMP SYSTEMS FOR SPACE HEATING

Research and development work in connection with components and systems for the utilization of solar energy concentrated in Austria in past years on the following subjects:

- o The development and testing of economical and efficient collectors and solar systems for swimming-pool and domestic water heating; the objective is to reach a life time of more than ten years.
- o The development and testing of heating systems with direct (collectors) or indirect (heat pumps) utilization of solar energy, special consideration being given to ecological and economic aspects.

In order to add to scientific findings specific data and experience with operating systems, the "Austrian Measurement Network for the Utilization of Solar Energy" was established in 1976. On behalf of the Austrian Federal Ministry for Science and Research 50 test stations with solar and/or heat pump systems were installed by the end of 1981. The Austrian Solar and Space Agency (ASSA) co-ordinates these test stations, evaluates the results and provides all those interested with the information required.

The experiments undertaken have contributed not only to the improvement of serial production of components and systems, but also to the establishment of standards and guidelines to be followed in the design, construction and operation of solar and heat pump systems.

3.1 Solar systems for domestic water and swimming-pool heating

Because of the meteorological conditions in Austria, solar technology can be used economically and efficiently only for swimming-pool heating (SH), in particular in the summer months, and domestic water heating (DWH), primarily from April to September.

The thermal energy output of a solar system depends to a large extent on insolation, ambient air temperature and working temperature of the collector system. The latter will always be kept as low as possible, i.e. in the case of swimming-pool heating below 30 °C, and in the case of domestic water heating below 50 °C. Under these conditions, about 25 to 30 per cent of incident solar energy can be converted into useful energy. Thus, about 300 to 350 kWh of the total incident radiation of 900 to 1400 kWh per m^2 collector area and year can be used in the form of low-temperature heat (300 to 350 kWh/m^2a).

3.2 Solar systems and heat pumps for space heating

As mentioned above, a seasonal (water) storage would be required for the direct utilization of solar energy for space heating. The large collector areas and big storage volumes thus necessitated make an economic heating of modest houses by these means improbable.

Both collector area and storage volume could be considerably reduced by using a heat pump in the system. However, in the case of heating systems with collectors, water storage and heat pump, collector area and storage volume have to be optimized from an economic point of view. Such a system has been tested in the Solar House Göfis, Vorarlberg, since 1978. The living area to be heated is 225 m^2. The heating system is composed of a 60 m^2 collector area, a 60 m^3 water storage and a heat pump with a electric load value of 2.2 kW. As auxiliary heating systems a stove with 8 kW heating capacity is used for space heating and an electric continuous-flow waterheater with 8 kW heating capacity is used for domestic water heating.

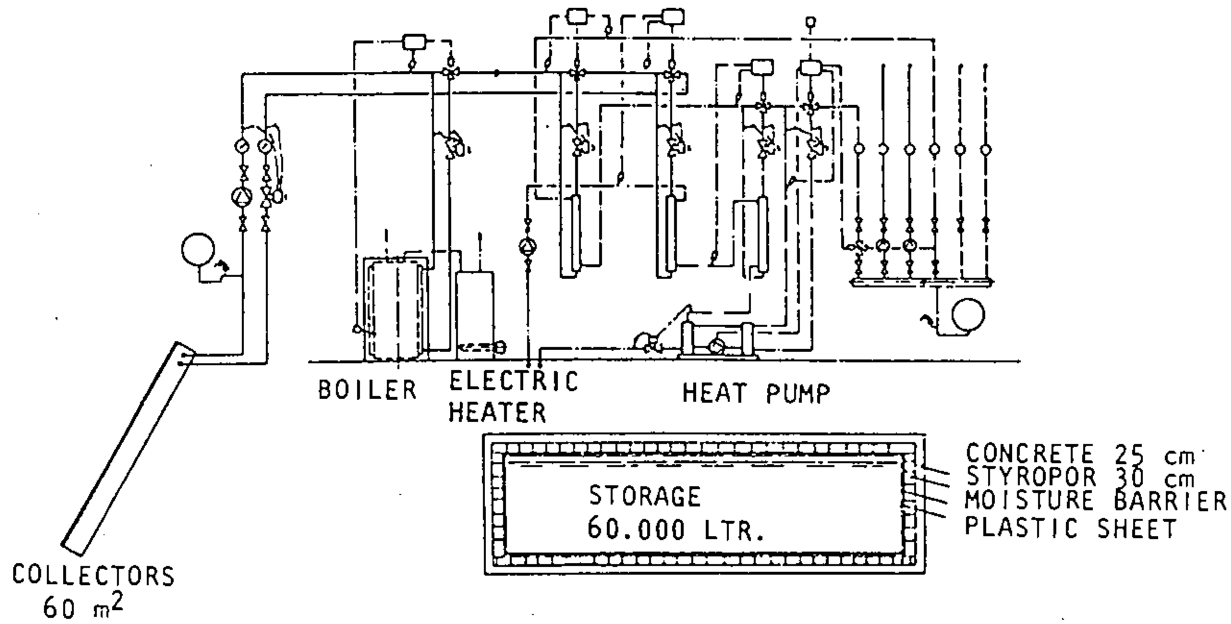
The use of collectors with transparent covers in heat pump systems has the advantage of providing the heat pump with higher-temperature heat and thus improving its COP (coefficient of performance). At the Solar House Göfis a COP of up to 5.4 has been achieved.

At the Solar House Göfis about 65 per cent of total heat demand could be covered by means of solar energy; figure 3.

A heating system composed of collectors with transparent covers, hot water storage and a heat pump is useful and should be installed in areas with favourable in-

FIGURE 3: ENERGY BALANCE OF THE SOLAR-HOUSE "GÖFIS"

PERIOD	SOLAR RADIATION ON COLLECTOR AREA kWh	ENERGY DEMAND FOR DHW kWh	SOLAR ENERGY FOR DHW kWh	ENERGY DEMAND FOR SPACE HEATING kWh	SOLAR ENERGY FOR SPACE HEATING kWh	SOLAR ENERGY/ TOTAL ENERGY DEMAND
1.I...31.XII.1978	79.995	11.535	6.212	37.189	22.333	58,5%
1.I...31.XII.1979	70.148	10.870	6.407	34.085	20.344	59,5%
1.I...31.XII.1980	63.393	9.097	6.478	35.928	22.990	65,4%



solation. Locations having long periods of fog are not suitable.

During the heating season 1981/1982 the heat insulation was removed from the water storage. The water in the storage was heated during the summer months up to a temperature of about 40 ^{o}C. During the heating season 1981/1982 the water storage was never cooled down below +5 ^{o}C by the heat pump; heat was taken from the surrounding ground. The results obtained with this low-temperature storage were similar to those of previous test years: about 65 per cent of heat demand for space and domestic water heating could be covered by solar energy.

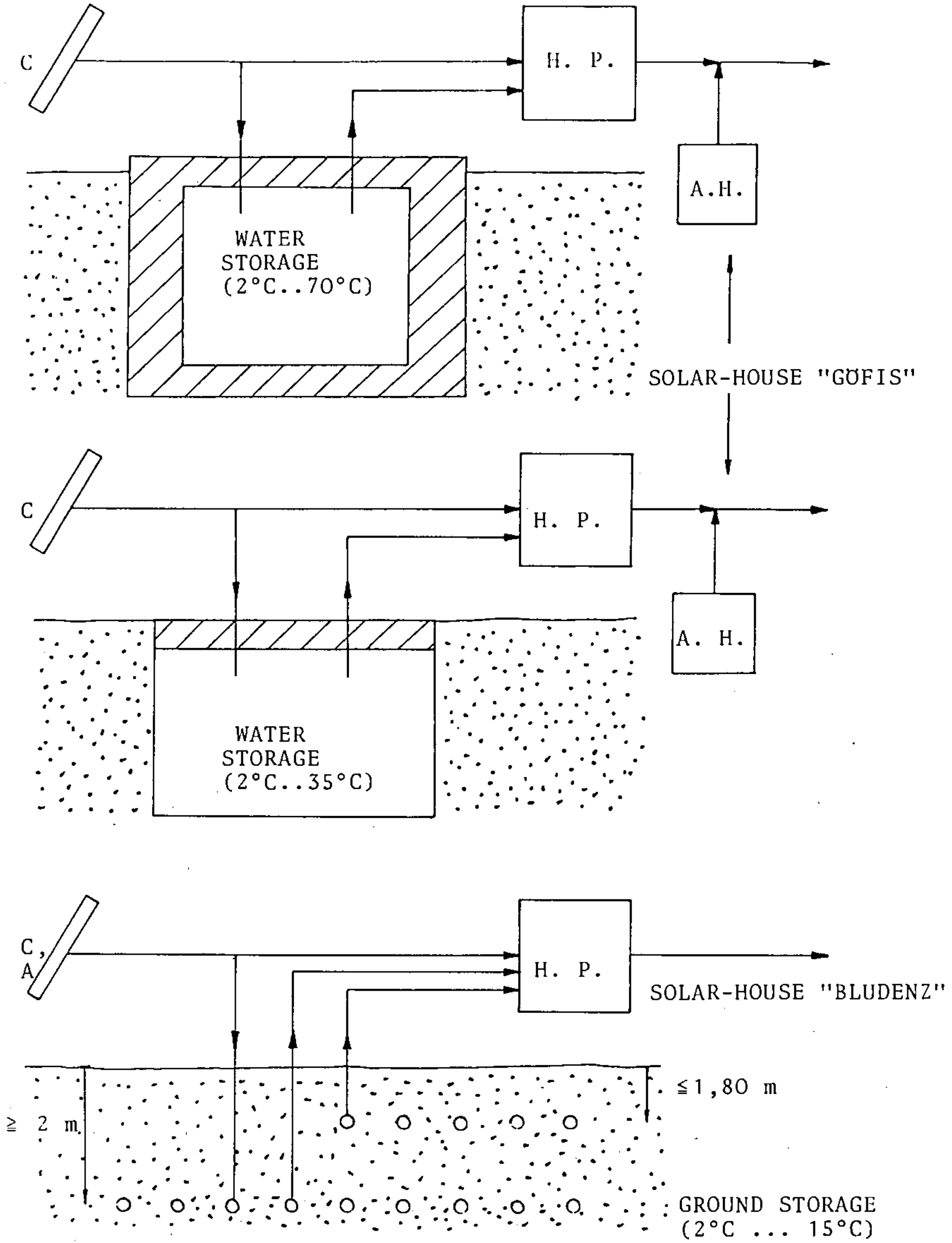
The costs of a heating system comprising collectors, low-temperature storage (a water storage without heat insulation) and a heat pump are about 20 per cent lower than those of a heating system whose water storage is well insulated. Still, the total costs will reach about AS 400,000 which is about 40 to 60 per cent of the total construction costs of the house.

Space heating in modest houses is expected to be more economic, if no artificial seasonal water storage is necessary. As a source of heat the upper layers of the ground could be utilized, as they, after being cooled down during the heating season, are heated by solar irradiation during the summer until they reach their original temperature.

The possibility of using a ground-coupled heat pump system for space heating was examined in the Solar House Bludenz; the results will be discussed later on.

Figure 4 shows the various test stations in Austria with collectors and heat pumps connected to a storage and used for space heating.

The experiences gained at the Solar House Bludenz have encouraged the utilization of optimized ground-coupled heat pump systems for the heating of modest houses. Such heating systems are now offered on the market for houses with a load of up to 15 kW (i.e. a living area of about 130 m^2) at between AS 150,000 and AS 200,000 including installation. In the case of a low-temperature heating with a maximum inlet temperature of up to 45 ^{o}C heat pump COP values of up to 3.3 are achieved.



C	COLLECTOR WITH TRANSPARENT COVER
A	ABSORBER
H.P.	HEAT PUMP
A.H.	AUXILIARY HEATING SYSTEM

FIGURE 4: PRINCIPAL WAYS FOR SOLAR ASSISTED HEAT PUMP SYSTEMS FOR SPACE HEATING: DEMONSTRATION PROJECTS IN AUSTRIA

If the soil is humid and loamy, collectors can retrieve from the ground between 15 and 30 W of heat capacity per m^2.

Usually the pipes are laid in a depth of about 1.5 to 1.8 m. The ground storage area required for the heating of a house with a specific heat demand of 80 W/m^2 would be about double the living area to be heated.

The ground area required for the operation of a ground-coupled heat pump system is not always available. If it is insufficient, there are several ways of operating the heat pump:

- o Combination with an auxiliary heating system;
- o Combination with an absorber;
- o Installation of two parallel planes of pipe and connection with an absorber.

Such heating systems are being tested at several test stations in Austria at present.

Based on experience gained at the Solar House Bludenz, a ground-coupled heat pump system was designed for a housing estate at Rankweil, Vorarlberg, and finished by the end of 1981. A ground-coupled heat pump system supplies the load of 69 apartments in eight smaller and six larger houses. In addition, a Total Energy System (TOTEM) consisting of five units and with an electrical output of 15 kW each is used.

The heat demand of the larger (multi-storey) houses is covered by two heat pumps with a connected load value of 30 kW each, for the operation of which electricity is supplied by the block power plant, and who retrieve heat from the ground. Two planes of plastic pipe (about 20,000 m), each plane covering an area of 6000 m^2, are buried in the ground at a depth of 1.5 and 2.5 m, respectively. In order to regenerate the deeper plane (below about 1.8 m), the domestic reject heat from bathroom, kitchen and toilet is led through PVC-pipes of suitable dimensions to the ground.

By recovering heat from the exhaust air from bathroom and toilet, additional heat is supplied to the heating system via an air-water heat pump.

The eight smaller houses are supplied with energy by ground-coupled heat pumps for which again the TOTEM provides electricity.

At Rankweil, an automatic data collection and processing system was installed. Measurements were first undertaken in May 1982.

4. THE SOLAR HOUSE BLUDENZ

The Solar House Bludenz was constructed from 1977 to 1978. One large and one small apartment were built on 200 m^2 living area. The house was built on a South-facing slope and passive elements for the utilization of solar energy were incorporated; i.e. the South-facing wall has a glass cover with adequate heat-protection during night hours and the building itself acts as storage medium.

The heating system is composed of -

- o an absorber
- o a ground-coupled storage on two planes
- o a heat pump.

Measurement data of the heating system have been evaluated since 1978.

Figure 5 shows the climatic data of the site.

The heat load of the building is 9 kW, the annual heat demand was calculated to be 72,000 MJ (20,000kWh).

4.1 System operation

Figure 6 shows the design and a schematic of the hydraulic scheme of the heating system.

The characteristic data of the heat pump, the asphalt absorber and the ground-coupled storage are listed in figure 7.

FIGURE 5: CLIMATE DATA ON SITE OF THE SOLAR-HOUSE "BLUDENZ"

Location: A-6700 Bludenz
Latitude: 47 ° 10' N

Average temperature of 1981	:	+ 7,4 °C
Average temperature of June 1981	:	+ 15,4 °C
Average temperature of December 1980	:	- 3,2 °C
Yearly solar radiation on horizontal m^2, 1981	:	3866 MJ (1074 kWh)
Solar radiation on horizontal m^2, June 1981	:	538 MJ (150 kWh)
Solar radiation on horizontal m^2, December 1981	:	83 MJ (23 kWh)
Yearly average wind speed, 1981	:	$\leq$ 2 m/S

The heat pump removes heat from the non-insulated ground-coupled storage by means of a circulating medium (water-glycol). As soon as the temperature in the asphalt absorber becomes higher than that in the ground-coupled storage, the motor valve MV_1 (figure 6) switches to the water-glycol cycle of the asphalt absorber.

Outside the heating season the asphalt absorber heats the lower configuration of pipe in the ground-coupled storage.

The asphalt absorber has an area of 120 m^2 and was installed on the access road and on the place in front of the garage.

Domestic water heating is separated from space heating and is undertaken by a solar system with a collector area of 8 m^2 and an electric auxiliary heating.

Figure 8 shows the mean temperature of the circulating medium in the ground-coupled storage. The temperature in the ground-coupled storage is about +15 ^{o}C at the beginning of the heating season and about +2 ^{o}C at the end of the heating season.

The amount of heat removed from the ground-coupled storage in the course of a year is shown in figure 9.

The relative temperature swing (RTS) is calculated as follows:

$$RTS = (T_{max} + T_{min} - 2 \times T_{ground}) / (T_{max} - T_{min}) =$$

$$= (16.5 + 0 - 2 \times 5) / (16.5 - 0) = 0.39$$

The ground heat exchange power is 6 W/m if the temperature of the circulating medium is about 5 ^{o}C.

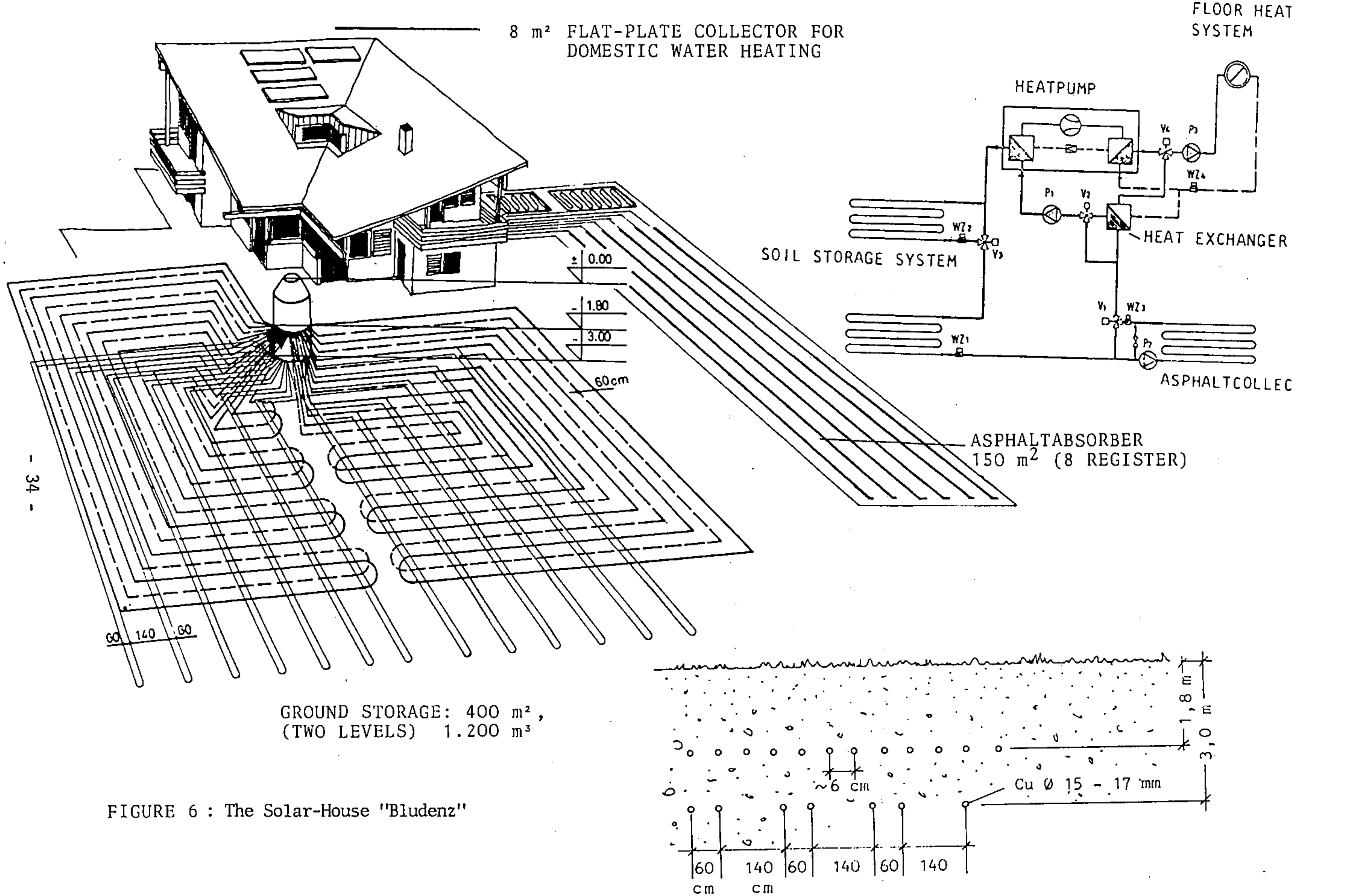


FIGURE 6 : The Solar-House "Bludenz"

FIGURE 7: TECHNICAL DATA OF HEAT PUMP, ABSORBER AND GROUND STORAGE AT THE SOLAR-HOUSE "BLUDENZ"

Heat pump data:

Heat pump brand	:	GEA-Happel
Heat pump type (water/air etc.)	:	water
Compressor type	:	full hermetic compressor
Refrigerant	:	R 22
Heat capacity	:	8 kW at T_{evap}= 273 K and T_{cond}= 310 K
Heat pump drive	:	electric motor

Asphaltabsorber:

Working fluid, Freeze protection	:	alcohol-glycol (-20 ^{o}C)
Collector aperture area	:	150 m^2, Asphalt
Orientation (azimuth)	:	South
Tilt	:	10 %
Efficiency (May to September)	:	9...12 %

Ground storage:

Storage type and material	:	Sand
Mean density	:	1.900 kg/m^3
Mean heat capacity	:	1.050 J/kg ^{o}C
Thermal conductivity	:	0,6 W/m ^{o}C
Ground water level	:	$\geq$ 60 m
Ground water flow rate	:	$\geq$ 50 m/year
Gross volume	:	1.200 m^3
Natural ground temperature	:	8 ^{o}....3 ^{o}C
Piping material and dimensions	:	copper, diameter 15.....17 mm

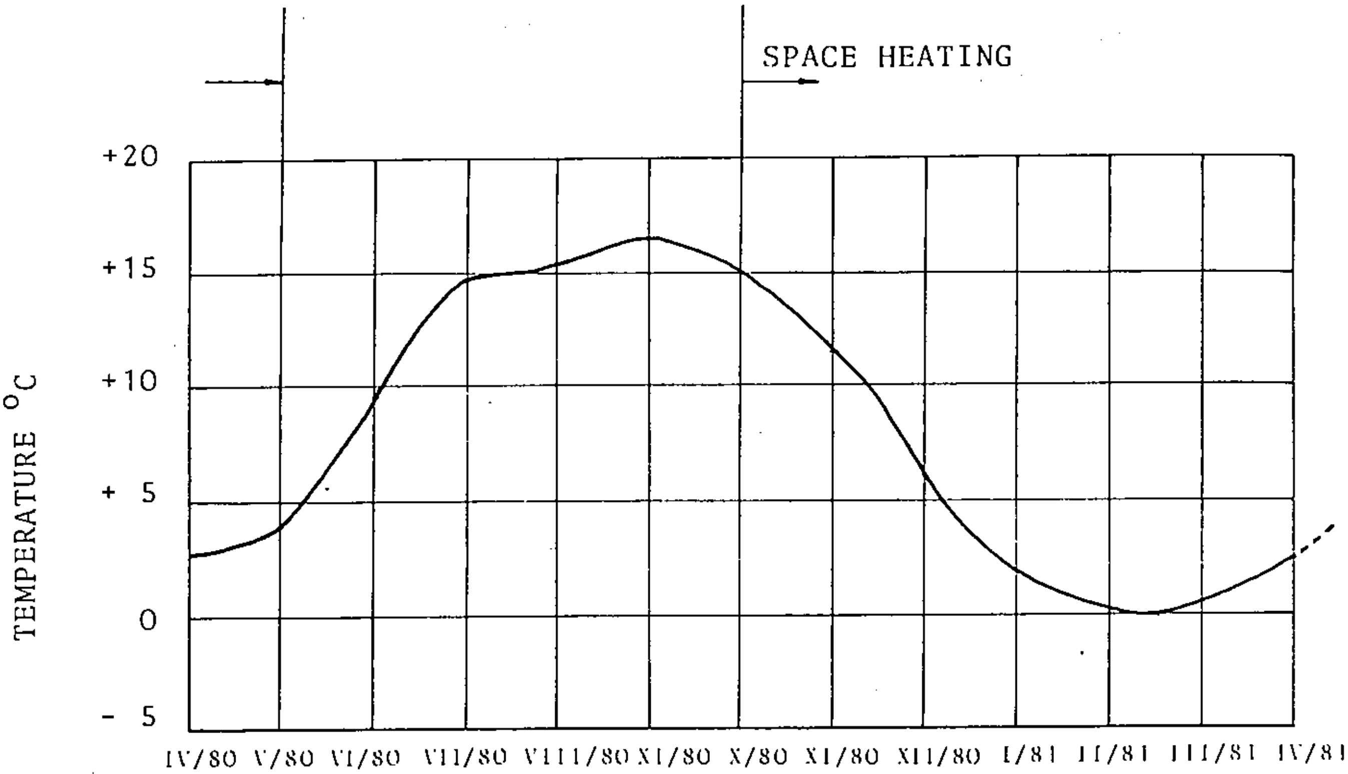


FIGURE 8: GROUND STORAGE MEAN TEMPERATURE VARIATIONS DURING ONE YEAR

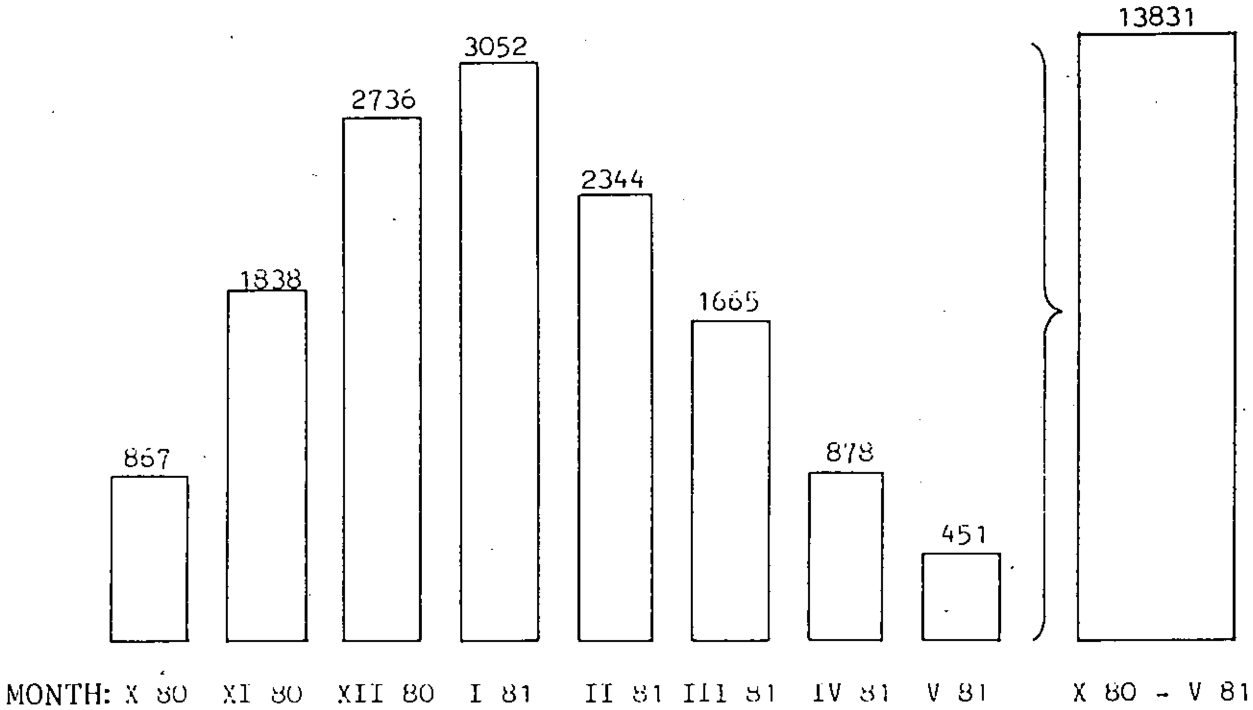


FIGURE 9: MONTHLY ENERGY FROM GROUND STORAGE IN kWh

4.2 Thermal performance

The thermal performance of the heating system is indicated in figure 10 on an annual basis.

The performance indicators and the measured energy quantities are listed in figures 11a and 11b on a monthly and an annual basis.

Figure 12 shows the energy balance of the heating system in the Solar House Bludenz. Up to 62 per cent of the total demand for useful energy of the house could be taken from the ground-coupled storage.

In the Solar House Bludenz the ground collectors are installed in two planes over an area of 400 m^2, which is equal to double the living area to be heated. During the heating season 1981/1982 several pipe registers were taken out of operation and only 160 m^2 of ground collectors were used for operating the heat pump. The temperature of the circulating medium has even in this case not gone down below 0 ^oC.

4.3 Economics

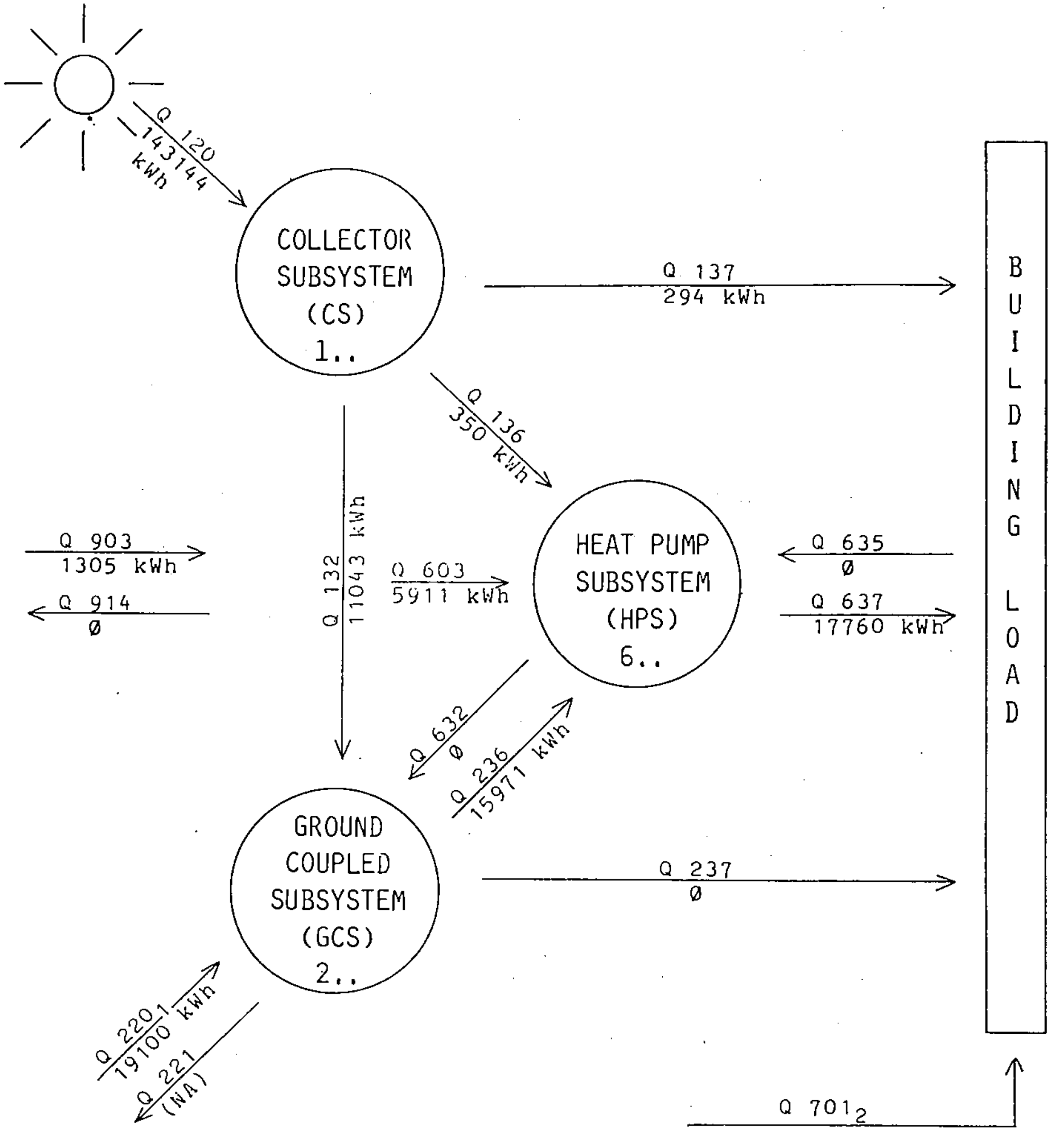
Between 12,000 and 16,000 kWh of renewable energy are obtained per year by means of the "ground-coupled storage - absorber - heat pump system" installed in the Solar House Bludenz.

The installation costs of the heating system are as follows:

Ground-coupled storage	AS 150,000
Asphalt absorber	AS 36,000
Heat pump	AS 54,000
	AS 240,000

Additional expenditures to the amount of AS 460,000 were incurred in connection with the measurement station.

The data and experience obtained at the Solar House Bludenz show that the installation costs of the heating system could be reduced by about AS 80,000 if the ground-coupled storage is optimized.



1 · estimated

2 · Wood, estimated

FIGURE 10: SYSTEM ENERGY FLOW DIAGRAMME

FIGURE 11a: MESURED ENERGY QUANTITIES ON MONTHLY BASIS

Q 137 + Q 136 + Q 132
Energy from CS

1979	Q 137	Q 136	Q 132	
I			Ø	
II			380	
III		80	430	
IV		120	1540	
V	75	150	2725	
VI	68		2190	
VII	67		1700	
VIII	27		1190	
IX	57		774	
X			114	
XI			Ø	
XII			Ø	
kWh	294	350	11043	11.687

Q 236 + Q 237
Energy from GCS (79/80)

	Q 236	Q 237
X/79	652	
XI	2396	
XII	2650	
I/80	3610	
II	2190	Ø
III	2100	
IV	1803	
V	570	
kWh	15971	Ø

Q 603 = Operating energy to HPS

	Q 603
X/79	213
XI	849
XII	969
I/80	1301
II	927
III	798
IV	653
V	201
kWh	5911

Q 637 = Heating energy from HPS

	Q 637	
X/79	724	
XI	2700	
XII	2949	
I/80	3920	
II	2499	
III	2363	
IV	1952	
V	658	
kWh	17760	

FIGURE 11a: (CONTINUED)

Q 137 + Q 637 + Q 237 + Q 701
Total energy to building load

	Q 137	Q 637	Q 237	Q 701	
X/79		724		180	
XI		2700		580	
XII		2944		560	
I/80		3920		440	
II		2499		340	
III		2363	Ø		
IV		1952			
V	75	658			
VI	68	Ø			
VII	67	Ø			
VIII	27	Ø			
IX/80	57	Ø			
kWh	294	17760	Ø	2100	20.154

Q 137 + Q 136 + Q 132	Energy from CS
Q 142 + Q 632	Energy to GCS
Q 236 + Q 237	Energy from GCS
Q 603	Operating energy to HPS
Q 637	Heating energy from HPS
Q 635	Cooling energy to HPS
Q 137 + Q 637 + Q 237 + + Q 701	Total energy to building load
Q 701	Auxiliary energy to building load

FIGURE 11b: PERFORMANCE INDICATORS ON ANNUAL BASIS

GCSE 1979/80	Ground coupled storage effectiveness = (Q236 + Q237 + Q120) / (Q132 + Q632) = (15971 + Ø + 381717 . 5%) / (11.043 + Ø) =	3,17
SPF	Total seasonal performance of the heat pump = (Q637 + Q632) / Q603 = (17760 + Ø) / 5911 =	3.00
CE	Collector efficiency = (Q137 + Q136 + Q132)/ Q120 = (294 + 350_1 + 11043) / 143.144 =	0,16
TSF	Total solar fraction = (Q137 + Q637 + Q237 + Q635 - Q903 - Q603) / (Q137 + Q637 + Q237 + Q635 + Q701) = (294 + 17760 + Ø + Ø - 1305 - 5911) / (294 + 17760 + Ø + Ø + 2100_1) =	0,54

1. estimated
2. WOOD, estimated

Q 903	Total operating energy for pumps e.t.c.
Q 914	Total nonuseable heat losses from other than collector and ground coupled subsystems.
Q 132	Controlled energy flow from collector subsystem directly to the ground coupled subsystem.
Q 137	Controlled energy flow from collector subsystem directly to the building load.
Q 136	Controlled energy flow from collector subsystem directly to the heat pump subsystem.
Q 220	Controlled energy flow into ground coupled subsystem from the surrounding environment.
Q 221	Controlled energy flow out of ground coupled subsystem into surrounding environment.
Q 237	Controlled energy flow from ground coupled subsystem directly to the building load.
Q 236	Controlled energy flow from ground coupled subsystem to the heat pump subsystem.
Q 632	Controlled energy flow from heat pump subsystem to the ground coupled subsystem.
Q 603	Controlled operating energy to the heat pump subsystem.
Q 637	Controlled energy flow from heat pump subsystem to the building load.
Q 635	Controlled cooling energy from the building to the heat pump subsystem.
Q 701	Total auxiliary energy for direct heating purposes.
Q 120	Global solar radition.

FIGURE 12: ENERGY BALANCE OF THE SOLAR-HOUSE "BLUDENZ"

P E R I O D	ENERGY DEMAND FOR SPACE HEATING kWh	ENERGY FROM SOIL STORAGE kWh	AUXILIARY ENERGY x) kWh	ENERGY LOSSES kWh	USEFUL ENERGY FROM SOIL STORAGE/ TOTAL ENERGY DEMAND %
1.X.1978...15.V.1979	17.602	14.726	6.677	3.801	62,1
1.X.1979...1.VI.1980	17.760	15.971	7.313	5.524	58,8
1.X.1980...31.IV.1981	15.857	12.502	6.219	2.864	60,8

x) FOR ELECTRICAL HEAT PUMP AND CIRCULATION PUMPS

4.4 Conclusions

The energy concept applied in the Solar House Bludenz has proven successful during four heating seasons. The annual costs of operation could be reduced by up to 60 per cent compared to an oil-fired heating system. During the heating season 1981/1982 the heating costs amounted to about AS 7,000; however, it has to be taken into account that electricity costs are relatively low in Vorarlberg and that the lower rate between 22.00 and 6.00 hours was used to advantage.

The heating concept of the Solar House Bludenz has been applied to several other houses. If the ground collectors are installed in two levels, the lower plane is heated by means of plastic collectors on the roof or by means of asphalt collectors.

IEA Solar Heating and Cooling Programme
Task II, subtask C, National Programme Overview

DENMARK

INTRODUCTION

The Danish Solar Energy Programme was initiated in 1977 as part of a general research and development programme set up by the Ministry of Energy. Each year a research organization can apply for grants to specific projects to be included in the next programme covering three years. Thus each year a new programme is initiated: EFP 82, EFP 83, etc. This means that a given project executed in 1982 is part either of the 80, 81 or the 82 programme.

The goal of the Ministry of Energy's Solar Heating Programme can be phrased as follows:

- to develop and distribute knowledge of the technical aspects of solar heating systems, and thereby achieve the best possible thermal performance, the best durability and a long lifetime of the systems.
- to contribute to a development within the solar heating field, with the purpose to help solar heating systems to be competitive with other energy sources so that they, in a long view, can contribute to the energy supply (especially heating) in Denmark.
- to estimate what kind of influence solar heating systems will have on the future energy supply in this country.

The main elements of the Solar Programme cover:

- domestic hot water heating
- combined space heating and domestic hot water heating
- passive solar
- seasonal storage

These subjects are of course on different development stages.

RECENT ACHIEVEMENTS

Domestic Hot Water Heating

Considerable amounts of work have gone into product development of both solar collectors and small water storage tanks. The result of this has shown up as improved performance characteristics of these products as well as very high measured outputs of two pilot test plants and two demonstration plants. This work continues now in the direction of improved cost effectiveness and reliability.

Experiments with a thermo-syphon system have shown very promising results and the potential of these systems under Danish conditions will be further investigated.

Domestic Space Heating and Domestic Hot Water

Systems for space heating have undergone extensive analyses, carried out on the basis of the detailed performance results obtained from the first generation systems erected as part of the demonstration programme.

The results of these analyses have been transformed into recommendations for the design of new systems of this kind. A prototype of such a new generation system is currently being tested as a pilot test plant. Following these tests a new demonstration installation will be built and monitored closely.

Also work on air systems has been initiated and will be continued during 1983 and 1984.

Passive Solar

In Denmark the designation "Passive Solar" is not very much used; usually "Energy Conservation" covers everything having to do with the reduction of energy needs for house heating. A lot of work is going on in the traditional areas of energy conservation: increased insulation, airtightness, heat recovery on ventilation air. Also a considerable amount of work is being carried out on the more "passive" concepts: direct gain, shutters, Trombé walls and attached sunspaces. A handbook is currently underway. Denmark is participating in both the CEC and the IEA programmes on passive solar energy. Special component research is carried out on Trombé walls with a very low loss coefficent. Computer models for various passive designs are under development, implementation and investigation (e.g. Blast).

Seasonal Storage

During the summer of 1982 a 500 m^3 test pit was erected and a monitoring programme initiated. As part of the cooperation within the IEA Solar Heating and Cooling Programme, Task VII, a large scale seasonal storage is being designed and optimised.

January 1983

Ove Jørgensen

September, 1982

JAPANESE R&D AND D PROJECTS ON SOLAR HEATING AND COOLING SYSTEMS

T. Hirono, T. Kamei
Sunshine Project Promotion Headquarters
AIST, MITI

and

T. Noguchi
Solar Research Laboratory, GIRIN
AIST, MITI

1. Potential projected energy contribution for solar heating and cooling in Japan

The Sunshine Project which has been inaugurated in 1974 might meet the demand of the new and renewable parts of the total energy consumption in the year 2000, and was accelerated in 1980 and modified in 1982.

Solar heating and cooling systems thus are expected to supply about 5 million kilo litres of oil equivalent in 1990, and 6.7 million kilo litres of oil equivalent in 1995 respectively, as the target of national energy policy in Japan.

2. Ongoing R&D and D Projects

Basic Researches:

- Solar Research Laboratory, GIRIN
  - Solar collector materials and testing
  - Solar collector testing procedures
  - Solar thermal energy storage
  - Solar pond
  - Photochemical energy storage
  - High temperature solar furnace works
- Electro Technical Laboratory
  - System analysis and evaluation of solar thermal-electric power system
  - Solar thermal energy storage
  - High temperature solar collectors

Development & Demonstration:

- New Energy Development Organization
  - SIPH system for textile industry
  - SIPH system for agricultural warehouse
  - Long term thermal energy storage
    - chemical reaction (metal hydrides)
    - underground

3. Level of Funding

Funding on Solar Heating and Cooling Projects in the fiscal year 1982 is described as follows:

	M yen	M $(US)
(1) R&D and D		
a) Basic Researches	176	0.68
b) Demonstration Projects	576	2.21
(2) Market analysis and Information	47	0.18
(3) Establishment of Reliability		
a) Insolation handbook, Survey of Special Solar System etc.	21	0.08
b) Solar Simulator Construction	532	2.05
(4) Commercialization	5,571	21.43

4. Relative Emphasis for Various Applications

In addition to the ongoing R&D and D projects on active solar systems, materials and components studies on passive system are supported to private sectors by the Housing Industry Division MITI. Ministry of Education has also been funding to 19 universities on passive system analysis and materials research, while MITI has been funding three solar desalination programmes as well as two solar pond programmes at this moment. Agricultural application is being accelerated by also private sectors, on such as green house and others.

5. Government Incentives

(1) Tax reduction of solar systems for commercial buildings

Deduction of solar systems cost or special amortization

Reduction of property tax

Local governments have their own local government tax reduction acts

(2) Loans to the small scale industries within the framework of budget (105.5 billion yen)

(3) Low Interest bank loans

5.5 % for residential house in 5 years

6 5 % for commercial buildings

6. Solar Water Heater Industries

More than 30 companies have been manufacturing solar water heaters which include both natural circulation (thermal syphone) type and solar water storage heater. Marketed products reached to 229,000 units in 1979, 756,000 units in 1980 and 476,000 units in 1981. The average area of these units is 2 m^2/unit.

7. State of Art of the Commercialization of Solar Heating and Cooling Systems

		1975-1980	1981	1982*	Total
Residential House	DHW	27,875	30,454	21,847	80,176
	H & DHW	625	63	19	707
	HC & DHW	60	8	----	68
	Others	6	----	----	6
Multi-family House	DHW	82	35	26	143
	H & DHW	2	2	----	4
	HC & DHW	6	----	----	6
	Others	----	----	----	----
Commercial building	DHW	1,159	1,302	540	3,001
	H & DHW	76	63	16	155
	HC & DHW	165	78	23	266
	Others	24	19	5	48
Industrial Process Heat	DHW	59	38	7	104
	H & DHW	4	5	----	9
	HC & DHW	10	1	1	12
	Others	25	11	3	39
Subtotal	DHW	29,175	31,829	22,420	83,424
	H & DHW	707	124	35	875
	HC & DHW	241	87	24	352
	Others	55	30	8	93
Total		30,178	32,079	22,487	84,744

Solar Collectors Marketed*

1975-80	1981	1982(June)	Total
350,182	306,696	186,308	843,186

*Excluding the solar water heaters.

8. Technology Transfer

New Energy Development Organization is making contract with UAE government to establish solar desalination plant of 100 ton/day, which consists of high performance evacuated tubular collectors and multistage flush evaporator.

9. Assessment & Follow Ups

The Solar Energy Committee of the Industry and Technology Council, Advisory Board to the Minister of MITI has been making overall assessment of Solar R&D and D policy.

The Sunshine Project Promotion Headquarters is in charge of Technical assessments on solar technology.

For the follow up of patents utility models and technical achievements, the Japan Industry and Technology Association is playing very important role.

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RESULTS OF THE DUTCH NATIONAL SOLAR R, D & D PROGRAM

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ABSTRACT

A survey is given of the Netherlands' Solar Energy R, D & D program. Achievements by mid 1981 are compared with the planning of mid 1978.

KEYWORDS

Solar energy; national R, D & D program; solar boilers; space heating; seasonal storage.

INTRODUCTION

The national solar R, D & D program in the Netherlands was formulated and officially started in 1978. It is based on the philosophy that, with the small budget available, those conversion techniques and/or those application areas should be developed first, that will be commercial first. As a result, the program is devoted entirely to production of low grade heat for different applications. Originally some 120 projects were formulated, of which about 90 at present are in preparation, underway, or have already been terminated. In the following, the organization and objectives of the program will be shortly commented upon, while the achievements of the main lines of the program will be compared to the original planning in terms of numbers of projects, budget spending, and main results obtained.

ORGANIZATION

On behalf of the Ministry of Economic Affairs the Project Office for Energy Research of the Netherlands Energy Research Foundation is responsible for the administrative and research management of the program. Projects are realized under contract with the Project Office by a large number of different institutions. Two thirds of the budget is supplied by the Ministry while the other one third is supplied by the contractors. On policy and management matters the Ministry is supported by an advisory committee. The program itself is divided into four budget periods with a duration of about four years each. Based on the philosophy mentioned earlier, in these periods R & D work on solar boilers, solar space heating, solar space heating in combination with seasonal storage, and cooling and climatization will be emphasized successively. The first of these periods, where the solar boiler is the main item, will expire by the end of this year. Furthermore, the program for each period is divided into a number of main lines of activity. The government budget for the first phase amounts to about US $ 20 million. To this, about 50% should be added as a result of contributions from the contractors. Not included in these figures are the expenditures for projects in which the national program does not participate financially.

OBJECTIVES

The main objective of the Dutch national program on solar R, D & D is to encourage a justifiable introduction and broadening of the applications of solar energy at minimum cost. For this purpose, knowledge and data will be accumulated for improving the performance and reliability of solar energy systems and their components, further reduction of cost, and the creation of a sound commercial activity.

GENERAL OBJECTIVES

- justifiable introduction
- expansion of application
- sound industry/market
- low cost

OBJECTIVES 1st PHASE

- demonstrate solar boiler
- recommendations for decision making
- prepare demonstration space heating
- explore seasonal storage and cooling
- study social consequences

Within the frame of the main objectives specific aims have been developed for the first phase. These include a technical demonstration of solar boiler systems, development of recommendations for introduction of solar boiler systems and the role of the government therein, development of solar space heating systems to a stage that makes technical demonstration in the next program period feasible, development of large scale, long term storage systems to a stage that makes experimental setups in the next program period possible, and finally, a study in depth of the social consequences of the introduction of solar energy.

SOLAR HOT WATER PRODUCTION

The solar boiler sub-program, which is the main topic of the present program period, is well under way as shown by the summary below.

SOLAR BOILER PROGRAMME

		Nr. of projects	
Activity	Funding	Planned	Started
R and D	$ 0.25 m.	6	2
field experiments	_ 0.35 m.	5	4
demonstrations	_ 1.42 m.	25	15
theoretical studies	_ 0.26 m.	4	3
social - economic	_ 0.20 m.	10	8

The planned government fundings shown have been increased with several hundred thousand dollars, while a shift in the budget has occured towards technical demonstration in the housing sector. The number of R & D projects is very small as a

result of the far advanced stage of development, where industry prefers to protect its own interests. However, one development in cooperation with industry should be mentioned. This should result by the end of the year in an entirely new solar boiler system at about half the current price including installation cost. The price of $ 1000 to $ 1200 aimed at, corresponds to a payback time (about eight years) comparable to the guarantee period (ten years).
All but one of the field experiments are combined with technical demonstrations. The latter category initially comprised five projects in each of the sectors housing, agriculture, industry, utility buildings and swimming pools. Demonstrations in the latter area have been cancelled because economic feasibility of commercial equipment is imminent. Moreover, the number of demonstrations in the housing area has been increased to ten, and in the other areas reduced to two. In addition, the budget for demonstration of domestic hot water systems has been increased substantially. This was necessitated by the fact that a much larger financial participation in the investments appeared to be necessary than initially anticipated. These projects comprise 25-200 families each and are spread both geographically and over the housing stock. Four of these are underway while the other six are in an advanced stage of preparation.
The theoretical studies have amongst others resulted in a well validated computer simulation program, which also has been internationally verified with good results. Of the social economic studies two results should be mentioned. Very important is, e.g., that by the end of this year a code of practice will be available for all professionals and consumers involved. It will include rather detailed recommendations for amongst others design criteria, design rules, cost effectiveness calculations and testing procedures. Finally, an economic and market study has shown that the technical potential for domestic solar boilers for the end of the century would be about 2.2 million. But in competition with improved hot water appliances only 450,000 will have been installed, corresponding to about 10% of the housing stock, to labour opportunities in excess of 10.000 man-year, and to an energy saving of 2×10^9 cubic meters of natural gas or 7×10^4 TJ.

SOLAR SPACE HEATING

Also this subprogram is well underway now. The survey below shows the expected funding at the start of the program. The overall budget has been reduced somewhat in favour of the solar boiler program and of some projects of a more general interest. The R & D budget has been increased while the budgets for field experiments and social economic studies have been reduced slightly.

SPACE HEATING PROGRAMME

		Nr. of projects	
Activity	**Funding**	**Planned**	**Started**
R and D	$ 1.02 m.	up to 20	14
theoretical studies	- 0.65 m.	5	5
field experiments	- 2.50 m.	up to 20	15
social - economic	- 0.73 m.	10	
passive	- 0.30 m.	5	3

Within the R & D sector one fundamental research project has resulted in a physical understanding and description of spectral selectivity. Furthermore, four projects are concerned with the development of complete collectors, four with collector parts including two industrial processes for spectral selective layers, three with short term heat storage, and finally two with a fundamental understanding of collector performance and development of test procedures. The latter project is carried out in close cooperation with other countries in the European Community

and in the International Energy Agency. It has resulted already in the availability of test procedures and test facilities, including a solar simulator with two test loops for, respectively, low and high temperature fluid cooled collectors and a loop for air collectors under construction. The theoretical studies are mostly concerned with system analyses, both of complete systems and of subsystems for different applications. They have also yielded a large computer simulation program which has been (and still is being) extensively validated against measured data from field experiments and test installations.
The field experiments comprise three agricultural applications, four office buildings, and eight projects in the housing sector. The latter comprise 82 dwellings of which 54 in one appartment building. The installations in all these projects are first generation systems. They have been, are being, or will be monitored extensively. The results will be compared with model simulations and will be used for further validation of the models. The actual performance data available now permit two preliminary but very clear conclusions. One is that it is not and will not be economically feasable to aim for installations with a maximum solar coverage of the heat load. Second, the first generation systems have been greatly overestimated so that the actual performance results are disappointing. This is mainly due to insufficient or even lack of knowledge of the performance of the installations and a number of their components, of the physical properties of a number of components, of the influence of the user habits on the performance, and some other less important factors. With this knowledge, the improved models, and further research and development work, it may be expected that second generation systems will perform much better technically, that their performance will be predicted more acurately, and that their cost effectiveness will be greatly improved.
The activities in the social economic area fall a bit short of the original planning. Of course a lot of information is generated by the field experiments with respect to non-technical problems. A market study has not yet been initiated as too much research and development work and systems analysis have to be performed before a reasonable estimate can be made about the cost effectiveness which should be the basis for an economic market study. Also development of a code of practice is delayed, but this will start immediately after the code of practice for solar boilers has been finished. Development of test procedures and test installations of course runs in parallel with the same activities for solar boilers as far as the collectors are concerned. As for short term heat stores, work has recently been started.

SEASONAL STORAGE AND COOLING

The plans for this subprogram have been rather drastically changed. The survey below, e.g., shows that studies on the possible application of solar cooling and climatization, have been cancelled. In fact, only some activity in this area is developed as an integral part of the studies of solar heating of utility buildings. What the survey does not show is that, although the number of field experiments on seasonal storage had to be reduced, the budget has been increased drastically.

SEASONAL STORAGE AND COOLING

		Nr. of projects	
Activity	**Funding**	**Planned**	**Started**
research	$ 0.31 m.	2	2
development	- 0.12 m.	1	1
field experiments	- 0.40 m.	3	1
cooling studies	- 0.12 m.	1	-

Research and development work and system analyses have resulted in a conceptual design of a central seasonal heat store for a group of hundred solar houses. The store uses saturated soil as a storage medium. It is loaded and unloaded through a vertical heat exchanger which is brought into the ground by a sort of huge sewing machine. For such a system the kWh price for solar energy was shown to be at most as high as for a single home with a solar installation with short term storage only. On this basis it was decided to realize an experimental set-up in order to gain more experience and to validate the relevant models. For this purpose the government has allocated an additional $ 3.4 mln. At present detailed design studies are underway and the start of the construction is expected by the middle of next year.

PROJECTS OF GENERAL INTEREST

Projects with a more general character or applicability are also well underway. The activities have reached a much higher level than originally anticipated as shown in the summary below by the increased funding.

PROJECTS OF GENERAL INTEREST

	Funding	
Activity	Planned	Present
climatological model	$ 0.12 m.	$ 0.24 m.
Pilot Test Facility	- 0.18 m.	- 0.56 m.
corrosion	- 0.20 m.	- 0.20 m.
I E A	- 0.18 m.	- 0.54 m.

To develop both detailed and simplified climatological models, the data base had to be expanded substantially. This is due to the very unstable weather conditions in the Netherlands.

Also the Pilot Test Facility needed an increased funding. After completion it will soon enter now its second two year period of operation. Apart from the activities coordinated and paid for by the European Community, the installation is used for testing of two types of collector, two types of heat store, and for validation of models. Shortly, also a completely new type of system will be tested. This consists of an enlarged solar boiler which can be used for supporting conventional space heating systems. Systems analyses have shown this could well be an economically optimal solution.

The Dutch participation in different IEA activities is also realized through the national R, D & D program. This includes participation in all tasks of the IEA solar energy program and in all but one of the tasks of the IEA program on energy conservation through energy storage. To the latter program a new task will be shortly added for which the Netherlands will act as operating agent and technical coordinator. This task involves testing of small scale, short term thermal storage systems.

CONCLUDING REMARKS

Above an outline is given of the Dutch national solar R, D & D program. The achievements since the start of the program have been described. A large number of activities has been initiated and partly already yielded results. These results are both promising and disappointing. However, they form a firm basis for further research, development and demonstration work. A new budget period with a new program, which is being formulated right now, will start at the beginning of next year.

NATIONAL SOLAR HEATING AND COOLING PROGRAMME IN NORWAY

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INTRODUCTION

Norway participated in Task II this year and is represented at the expert meeting for the first time. This paper will therefore deal with the Norwegian research and developing programme in general and try to give you a brief description of the status.

Norway has a very favourable energy situation and in 1981 we had an oil production 5 to 6 times the inland consumption. The hydro-electric power covers about 50% of the total energy demand. Hydro-electric power may according to present policy be increased by 50%. Approximately 30% of the total energy demand is energy consumption in buildings, and out of this is about 60% hydro electric. As a conclusion, renewable energy resources at present come to about 50% of the total inland energy demand and 60% of the energy demand in buildings.

SOLAR ENERGY RESEARCH AND DEVELOPMENT

On this background you will understand that the research activity on other alternative energy resources has not the highest priority in Norway. Below it is shown the level of governmental fundings for R & D for alternative energy from 1979 - 1982 in mill.NOK. (1 mill.NOK = 140.000 US$). Nominal prices.

	1979	1980	1981	1982
Biomass	1.1	2.9	3.2	4.6
Wave	16.0	16.2	12.8	9.0
Solar	1.5	3.1	2.7	2.2
Wind	2.9	2.3	2.8	2.2
Other	.4	3.0	8.0	8.5

As you can see most of the funding has been concentrated to wave-energy.

The table shows a top in 1980 for solar energy research and then a decrease until today. Our present funding corresponds to aprox. 5 to 6 man-years. Compared to our Scandinavian neighbours, the funding for solar energy research and development is quite moderate.

<u>COMMERCIAL SOLAR WATER HEATING SYSTEMS</u>

The main goal for the national R & D programme is over a 5 year period to evaluate the technical and economical possibilities for solar energy utilization in Norway.

The areas for emphasis are:

- to predict the solar radiation in different locations in Norway through simulation models and based on measurements

- a further development of cheap and simple solar energy systems.

The solar research activity in Norway differs from international research activity not only in economic, but also in technical ways. We have a very low activity in the field of commercial solar water heating systems. This is due to the fact that most of the residential buildings in Norway are heated with direct electrical heaters. Just a small percent of the detached houses have a central hot water heating system. This means that the commercial solar water heating systems can not be introduced in existing houses without changing the whole heating equipment. In new houses the cost of central heating is much higher than direct electrical heating, and the total cost for a solar water heating system would be far too high compared to electrical heating

Our electricity price is very low, NOK 0,20 per kWh (0.03 $/kWh), and most of the commercial domestic hot water heating systems to day can not compete with this energy price without any special grants or tax credits from the government. A good DHW system would

produce approx. 2.500 per year kWh and this can not justify the installation costs of the solar system.
Very few district heating systems are built in Norway, so the implementation of water collectors to this type of system is not very interesting either.

BUILDING INTEGRATED SYSTEMS

Most of the research activity has been concentrated on very simple systems, which very often are integrated in the building construction. This is a result of the philosophy that a very simple solar system with a relatively poor efficiency can yield just as much energy as a highly effective system by increasing the solar collector area. We have a feeling that these simple systems, even if they are slightly bigger, will be more cost-effective than the more complicated and highly effective systems.

Most of the building-integrated systems are solar air heating systems. We have also done some experiments with the double-envelope system, and the first house with this system was built in 1977. At present we have 4 different double-envelope houses.

Some of the integrated air systems have a very low installation cost compared to commercial water heating systems. One example is a sports hall having a 160 m^2 air collector with selective absorbator. The system has a heat exchanger for preheating hot water for showers and the total price is approx. NOK 80.000 (US$ 11.000). Simulations indicate an energy output of 50.000 kWh per year.

One Norwegian company makes prefabricated houses feating an integrated solar air heating system of approx. 60 m^2 solar collector. The additional investment cost compared to a normal house is approx. NOK 60.000 (US$ 8.500) all included, and the system has an energy output of 10.000 kWh per year.

One group is working with a modified Thommason trickle solar collector. They have managed to increase the efficiency of the collector up to that of a normal flat plate collector.

At present time much interest has been put on passive and hybride systems, and Norway is participating in the IEA Passive and Hybride Solar Energy Project.

We have a very low commercial activity in Norway. Just a very few heating systems are sold per year, both SH and DHW. The main reason is the high investment compared to our low electricity price. One aluminium company makes Roll Bond absorbators, mostly for exports. We also have a couple of minor companies making small systems for domestic hot water.

Most of the systems built so far are custom designed and built at the place with common building materials. Breakthrough for solar heating systems in Norway is likely to depend on a great cost reduction of the components and the systems, provided energy prises do not increase dramatically.

In general we handle most of the solar research projects in very close connection with energy conservation projects in buildings. In practice this means that the handling and condination of both solar heating and energy conservation projects is done by the same department of The Norwegian Technical and Scientific Research Council.

Approx. 25% of the solar funding covers solar radiation and meterological projects. The projects include radiation measurements and radiation simulations. This work is done in cooperation with the Norwegian Meteoroligical Institute.

At present we have no activities in the field of solar cooling.

29/10.82

Status of the United States 1982 Solar Heating and Cooling Program

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INTRODUCTION

The United States national solar heating and cooling program had its origins in legislation passed by the 93rd Congress in 1974. The thrust of the early program was to accelerate the use of solar heating and cooling products throughout the country. Concurrent programs were initiated to support research and development, to demonstrate the viability of current technology, to provide financial incentives for installing solar systems, and to increase the public awareness of the benefits of solar products.

Program funding increased rapidly from a few million dollars in 1974 to approximately 100 million dollars annually from 1977 through 1980. The programmatic emphasis remained relatively balanced between R&D activities and market development activities from 1977 through 1980.

The Department of Energy (DOE) was reorganized in the spring of 1981 to reflect the changing emphasis of the current Administration. The new Assistant Secretary for Conservation and Renewable Energy directed that the programs undertake long-term, high-risk, potentially high pay-off R&D through proof-of-concept to the exclusion of market-related projects and communications activities. Priority was to be placed on high-risk research and technology development activities which are not being undertaken by industry. In addition, the development and demonstration projects, along with many of the market and commercialization oriented programs initiated in previous years, were to be closed out.

To reinforce this change in emphasis, the organization was realigned by technology instead of end-use applications, which brought active and passive solar technologies into the Office of Solar Heat Technologies. Along with the shift in emphasis towards research, funding for the solar heating and cooling program has been significantly reduced since the reorganization. Program budgets were reduced from approximately $100 million in 1980 to $23 million in 1982.

Hence, 1982 has been a year of transition for the program. The most promising high-risk research activities have received greater emphasis, along with comprehensive planning efforts to define the future high-risk research program. Many of the most effective development and demonstration programs, initiated in earlier years, were brought to an orderly closeout, while other less promising, programs were terminated immediately due to lack of funds. Technology transfer activities have been maintained to insure that the key results of all programs are effectively transferred to the private sector.

The status of the U.S. Solar Heating and Cooling Program is outlined in detail in the remainder of this paper. To give some idea of the direction of the program's activities and accomplishments the first section will cover program goals and strategies. The following section, technology and industry status, will deal with solar heating and cooling activities up until 1982. The next major section covers both the focus of present R&D activities and the more recent program accomplishments. The final section briefly highlights the research activities to be undertaken in the 1983 solar heating and cooling program.

PROGRAM GOALS AND STRATEGIES

While the goal of replacing scarce non-renewable resources with cost effective solar energy is of ultimate importance, the 1982 current program goal reflects the technology research focus placed on current program activities. The goal of the program is to establish a technology base that will allow industry to develop a broad range of components, materials and systems that cost effectively heat, cool and light U.S. buildings. Specific technology goals are:

- Active Heating and Cooling -- Systems have been shown to be technically feasible; however, the performance, durability, reliability, and cost-effectiveness for widespread market acceptance does not currently exist. Hence, the FY 1982 program activities are directed towards achieving the following goals:

  - Improve the performance/cost ratio of active space conditioning systems by a factor of 2-4.

  - Improve long-term system performance, reliability, and maintainability to obtain systems capable of achieving 20 year service lives.

- Passive & Hybrid -- A 30% cost-to-performance improvement over state-of-the-art passive system materials and components is required to assure widespread adoption by the building industry. To be competitive with conventional energy sources, integrated systems must meet the following performance goals:

  - Residential buildings: Small scale passive systems must provide 60% of total building loads at an average system construction cost $100/MMBtu/yr.

  - Non-residential buildings: Large scale passive systems must provide 40% of total building loads at $250/MMBtu/yr. average system construction cost

The program focuses on advancing the state-of-the-art of solar heating and cooling, and relies upon private sector initiatives to bring solar heating and cooling technologies to the marketplace. The program works in close cooperation with industry and institutions, including international bodies, to insure that government activities focus on high-risk innovative research that has the greatest potential pay-off and do not duplicate efforts in the private sector. Private sector scientists and engineers participate with solar heating and cooling program managers on program planning and evaluation panels and committees. They also join DOE staff at periodic conferences where the results of private and Government sponsored research activities are reviewed and evaluated.

The program is balanced appropriately among exploratory research and development; materials and components development; systems design, test and evaluation; and technology transfer activities. The current program strategy can be separated into four major elements:

- Support of high risk, long-range R&D that has a high pay-off potential

- Support of proof-of-concept field tests in conjunction with industry, universities, state and local governments, and other Federal agencies

- Phase-out of technology development projects

- Documentation of findings from completed programs and transfer of the research results to industry.

INDUSTRY AND TECHNOLOGY STATUS

Government and industry efforts prior to 1982 have resulted in the growth of a relatively small, but viable solar heating and cooling industry. Substantial progress has been achieved in developing and marketing first generation active and passive solar heating systems. These technologies have received widespread interest from many diverse elements of the U.S. building industry. While interest has been high, the depressed state of the U.S. housing industry has slowed the rate of adoption of current solar heating technologies. The current status differs by technology and application.

ACTIVE SOLAR HEATING AND COOLING

The predominant product of the U.S. solar industry is the solar water heater. Over 350,000 systems are currently in use. Even with a depressed U.S. housing industry there were sales totalling $450 million in 1981, representing a 30% growth over 1980 sales. The sales level for 1982 is expected to remain at basically the same level as 1981. While there has been consolidation in the industry there are still over 50 major solar equipment and almost 2,000 installation firms in the field. Program activities have provided an important base for expansion of the active solar market.

- The DOE solar hot water program has produced and published a number of design handbooks and validated design tools for hot water systems. In addition, the program has supported the purchase of 10,500 residential, 70 commercial and 700 federal hot water systems.

- A technology base has been established for active space heating. The program has supported the development and testing of over 500 systems with new components and designs. Improved selective surfaces, low cost plastic films, and more efficient energy storage have been developed to lower system cost and increase reliability. Performance testing has been completed on 75 different space heating systems, and the data has been thoroughly analyzed. Also, the program has developed and tested 4 different solar-assisted heat pumps with COPs in the range of 9-10.

- Active solar cooling system prototype developments have been completed. Field tests of 3, 10, 25 and 200 ton cooling systems using both Rankine and absorption cycles have shown that the machines can achieve a steady-state COPs of 0.75 even with air cooling. In addition to the absorption and Rankine systems, a closed-cycle desiccant system has been built and successfully tested. In conjunction with the prototype development work performance prediction models have been developed for the various cooling systems.

PASSIVE AND HYBRID SOLAR

Passive and hybrid solar technology is in varying stages of development, with the most significant progress occurring in the development of residential heating systems. The performance of simple single-zone direct gain, indirect gain, and isolated gain systems can be predicted and has been measured. Consumer interest in passive solar has grown to the point where, according to recent surveys by the National Assocation of Home Builders and Housing Magazine, the general public understands the benefits of passive solar, and strongly prefers it over conventional energy sources. Industry has begun to produce passive systems commercially, since knowledgeable home buyers are willing to pay somewhat higher prices for a passive house than a comparable conventional home.

Advanced systems such as combined (e.g., direct and indirect gain), hybrid (active, passive, and photovoltaic), and multizone integrated systems (passive heating, cooling, and conventional heating, ventilation, and air-conditioning) still require additional R&D. A few of the major developments in the Passive and Hybrid Solar Program prior to 1982 are:

- A technology base has been established for first generation passive heating systems that can supply from 20 to 60% of the heating energy requirements (10-30% of the total energy requirements) in residential applications.

- The program has developed analysis methods and design tools for first generation residential heating systems. Performance data from 40 structures has been collected and analyzed. For larger passive systems, the program has initiated field testing of commercial buildings prototypes and established a performance data acquisition program. Seven of 23 prototype buildings had been completed prior to 1982. Over 50,000 passive buildings had been built and sold prior to 1982.

- The Passive and Hybrid program's applied research activities have resulted in a number of developments, including:

  - Heat mirror glazing being manufactured and commercially available

  - Phase-change wall assembly for energy storage under test

Also, the potential of passive cooling systems has been characterized. The initial quantitative description of single and multizone heat transfer mechanics has been completed and the initial cycle of experimental buildings have been constructed.

THE 1982 SOLAR HEATING AND COOLING PROGRAM

While active systems installed over the past several years have met with a fair measure of technical success, there remains a significant gap between measured system performance and reliability, and system's cost effectiveness potential. Recent investigations indicate that the performance to cost ratio of active space conditioning systems must be improved by a factor of two to four to ensure market competitiveness. In particular, major components such as solar collectors (currently representing 30 to 50 percent of installed system costs) must experience significant cost reductions or performance improvements.

Research and development efforts in Active solar focus on:

- Components and materials-to improve performance and reliability and lower the cost of basic materials and components for principal system elements -- collectors and chillers

- Advanced systems-to develop and test advanced systems capable of achieving cost competitive status

- Analysis and evaluation-to validate systems analysis tools based on performance data from state-of-the-art systems

During the past year it has been shown that passive and hybrid solar technologies have the potential to (1) essentially eliminate auxiliary energy reqüriements for space heating in most regions of the nation, and (2) reduce cooling and heating energy consumption by more than 50%. These potentials can be realized if significant advances are made in the materials sciences and if the research in these two areas properly progresses from conceptualization through development testing to evaluation. For Passive and Hybrid systems, research and development activities concentrate on:

- Collection-to improve materials and systems to reduce unwanted gains or losses (5% of total U.S. energy end-use is related to aperture inefficiencies)

- Storage-to develop and select materials to eliminate the potential for overheating and increase passive effectiveness

- Systems-to establish passive cooling design base and to analyze and measure the performance of multizone integrated heating, cooling and daylighting systems.

The total budget for the solar heating and cooling program was $24.1 million in FY 1982. A breakdown of the program budget by major program element and a comparison with FY 1981 is presented in Table 1.

With the change in program focus toward long-term, high risk, potentially high pay-off R&D, many industry-support projects -- which had been continued from earlier years -- were completed during 1982. Results of these programs have proven to be of great value to the emerging, financially constrained solar industry. The following summary of 1982 accomplishments, reflects projects that are fully consistent with current policy direction as well as some that had been initiated under earlier strategies.

1982 ACCOMPLISHMENTS

While Active solar systems are technically feasible in a variety of hot water, space heating and cooling applications, the performance, durability and cost-effectivness to meet major unsubsidized U.S. market needs does not exist. Substantial progress to enhance the performance and/or cost of active system components was made during 1982.

- A high performance thin film polymer laminate collector was designed and prototypes were produced. Several engineering problems concerned with manufacturing the collector were solved and one significant problem area -- delamination of the absorber -- was identified.

- The first phase of development of an innovative high temperature air-cooled absorption chiller was completed. Progress was made on both single effect and double effect regenerative chillers, with completion of a simplified design for the final generation single effect machine and construction of a test-bed for the double effect machine.

- Four contracts were awarded for the development of innovative, cost-effective, and reliable packaged residential space heating systems. The innovative system designs are expected to lower installed system cost and significantly increase system reliability.

Other significant program milestones were met during 1982. For example, numerous research and engineering projects supported the development, by the industry, of consensus test and evaluation procedures that provide a uniform technical basis for measuring the performance and establishing an engineering data base on active solar heating and cooling systems, components and materials. Early demonstration programs have been successfully completed, with construction of all but 18 out of 216 commercial demonstration projects. In addition, 568 out of 763 Federal government projects became operational in 1982.

Several important Active heating and cooling program planning activities were also completed:

- Detailed research reviews were prepared for eight potential materials research areas. An analysis of the potential for cost reduction was made and the research areas were ranked to establish program priorities.

- Evaluation of presently available solar heat pump systems have shown that they generally do not provide a cost-effective use of solar energy.

Substantial progress has been made in several key Passive and Hybrid technology research areas.

- In the area of aperture materials the initial research phase has produced the following results:

  - A transparent film that reflects long wave infrared radiation and that can be mounted directly on glass has been successfully developed and produced

- Several optical switching films have been developed and their performance is currently being studied

- High transmission insulating materials have been studied, their optical properties measured and their thermal properties have been calculated

- Progress has been made in the area of phase-change thermal storage. A number of promising stable materials, including organic solid solutions of pentaerythritol ($C_5H_{12}O_4$), pentaglycerine ($C_5H_{12}O_3$) and neopentyl glycol ($C_5H_{12}O_2$) have been identified.

Several programs, which involve the design, construction, and monitoring of first generation passive buildings have produced important results.

- The Passive Solar Commercial Experimental Buildings Program has resulted in the construction -- and occupancy -- of 15 buildings, that incorporate passive heating, cooling and daylighting features. Initial results indicate that energy savings can be as high as 86% over similar conventional buildings. Detailed performance data will be gathered to produce the largest available data base describing commercial building energy use.

- The Passive and Hybrid Manufactured Buildings Program addresses the issues associated with incorporating passive solar concepts into manufactured buildings. In 1982, designs were completed for 22 different buildings and 8 prototype buildings were built. Performance monitoring is currently underway on these buildings.

- The Performance Monitoring Program has developed a uniform testing methodology, and effectively modified and installed data acquisition hardware on 63 sites across the nation. A plan to transfer this monitoring capability to industry has been initiated.

LOOKING FORWARD TO 1983

Recent changes in the world energy markets have made it more difficult for the current generation of solar heating and cooling technologies to compete in the U.S. marketplace. In 1983 the program will focus a substantial amount of its resources on the investigation of new lower cost materials and integrated system designs. Increased emphasis will be placed on integrating passive and active solar concepts with conservation technologies to solve building energy problems.

With a lower level of funding in 1983 -- the program funding mark established by the U.S. House of Representative is $11.6 million -- the research efforts must become more selective. As part of this reduction in scope, active and passive solar technologies will be targeted towards different, specific applications to take maximum advantage of the limited research funds.

There is enormous potential to reduce conventional energy use for heating, cooling and lighting by increasing the effectiveness of glazing materials. Both active and passive systems are presently at a disadvantage relative to conventional technologies for supplying cooling to buildings. However, advances in glazing materials and daylighting techniques have the potential to significantly lessen building cooling requirements.

Future research activities will focus on the development and testing of advanced, low cost/high performance materials and components. Specifically, future research efforts in the Active Solar Heating and Cooling Program will include:

- Research and-Technology Development -- The focus will be on research to develop new or improved materials and components. Also, program activities will establish basic information on the thermal, physical, and optical propertes of materials and components in use, or intended for use, in active systems.

- Systems Test and Evaluation -- This program element will provide industry with the short- and long-term system level data and analysis tools necessary to support decisions regarding active technology development needs. The focus will be on the collection, processing, analysis, and dissemination of thermal performance, reliability, and maintainability data.

For the Passive and Hybrid Systems Program, research efforts will emphasize:

- Development of a technology base supporting passive cooling and lighting systems that will reduce electricity consumption in the nonresidential buildings sector by 60% beyond state-of-the-art building technologies.

- Development and evaluation of advanced concepts for passive heating of buildings that improve performance by factors of 2 over current technology while simultaneously mitigating the adverse effects that current heating technology has on off-season performance.

- Continuation of applied research in design tools and performance evaluation, and information dissemination activities, applicable to first generation passive heating technologies which are largely relevant to the residential sector.

TABLE 1

DOE Solar Heating and Cooling Budget

($ Millions)

Passive Program Elements		FY 81	FY 82
Residential Systems		$17.0	$ 4.4
Nonresidential Systems		8.7	3.9
Materials & Components		2.9	3.8
Solar Cities & Agriculture		2.1	-
Capital Equipment		0.5	.5
	TOTAL	$31.2	$12.6

Active Program Elements		FY 81	FY 82
Advanced Research & Analysis			
Component research		4.8	4.9
Materials research		.9	1.6
Systems Development			
Advanced systems		10.8	2.0
Analysis & evaluation		7.1	2.2
Industry Support		16.6	.3
Capital Equipment		1.3	.5
	TOTAL	41.4	11.5

UNITED STATES 1982 SOLAR HEATING AND COOLING

PROGRAM OVERVIEW

DEPARTMENT OF ENERGY
WASHINGTON, DC

OFFICE OF SOLAR HEAT TECHNOLOGIES

GOAL

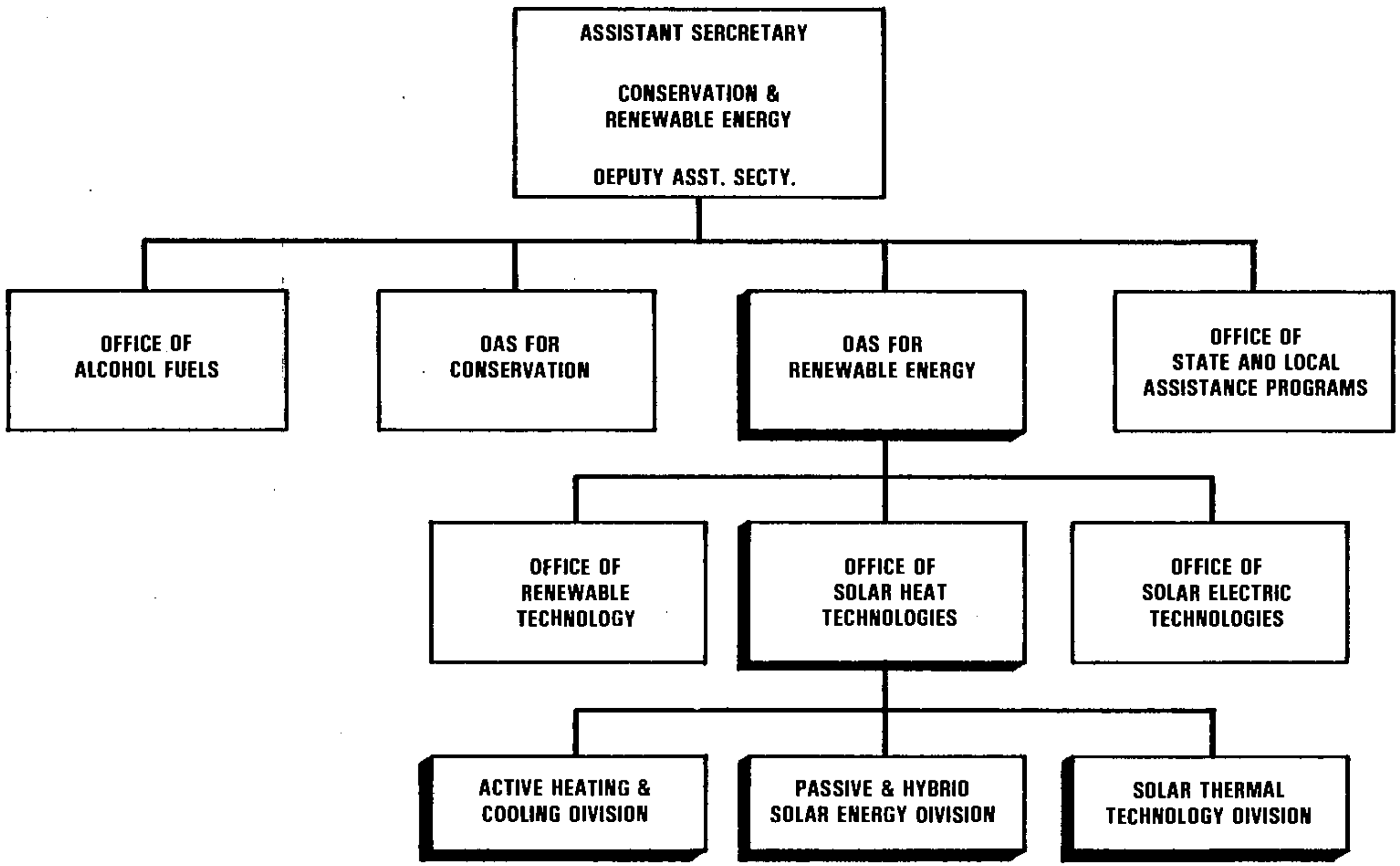
THE GOAL IS TO ESTABLISH A TECHNOLOGY BASE THAT WILL ALLOW THE BUILDING, MANUFACTURING, CHEMICAL AND UTILITY INDUSTRIES TO DEVELOP A BROAD RANGE OF COMPONENTS, MATERIALS AND SYSTEMS THAT COST-EFFECTIVELY CONVERT SOLAR ENERGY INTO USABLE THERMAL, ELECTRICAL, AND MECHANICAL POWER AND FOR THE PRODUCTION OF PETROCHEMICAL SUBSTITUTES.

OFFICE OF SOLAR HEAT TECHNOLOGIES

STRATEGY

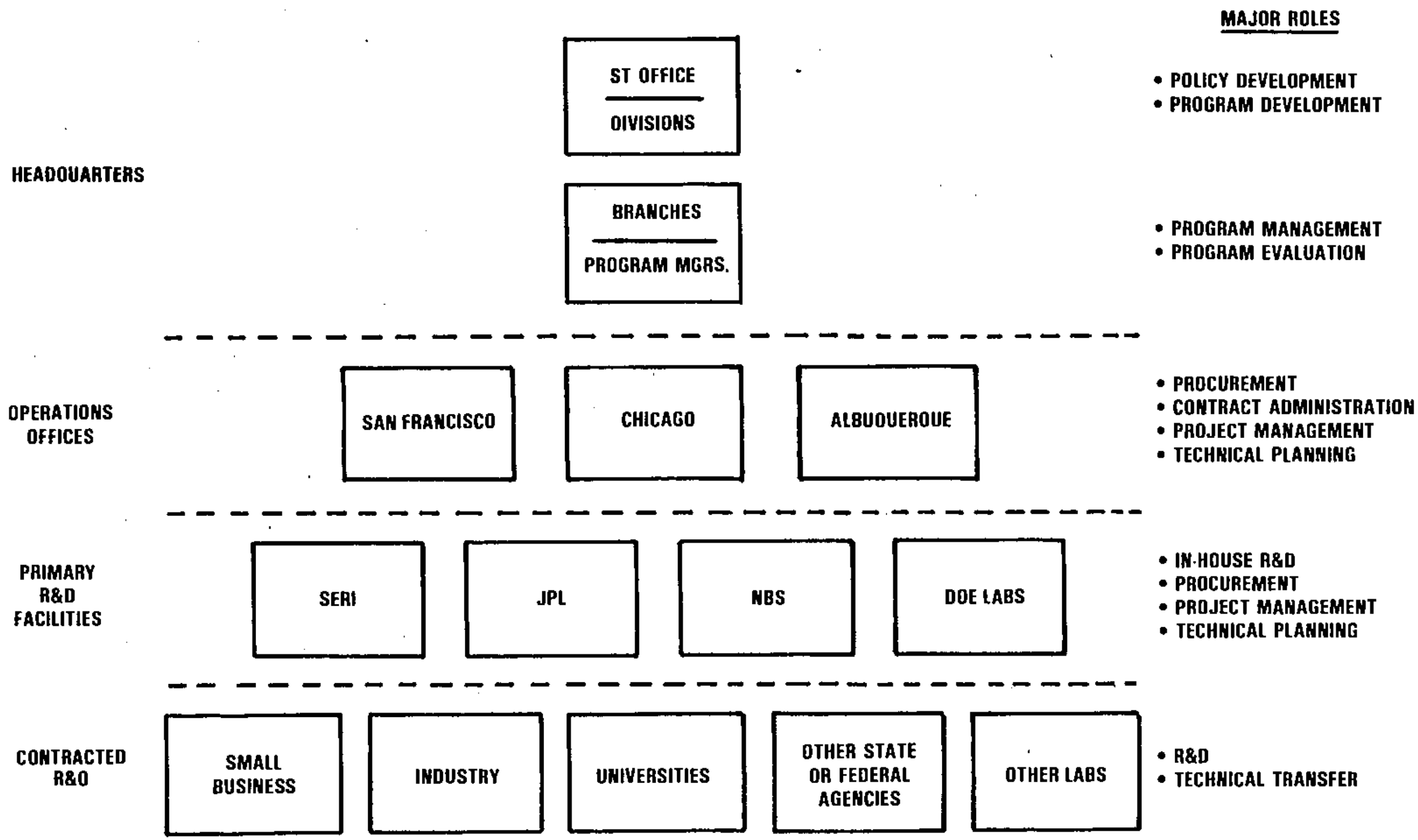
- SUPPORT HIGH RISK, LONG-RANGE R&D THAT HAS A HIGH PAYOFF POTENTIAL
- SUPPORT PROOF-OF-CONCEPT FIELD TESTS IN CONJUNCTION WITH INDUSTRY, UNIVERSITIES, STATE AND LOCAL GOVERNMENTS, AND OTHER FEDERAL AGENCIES
- PHASE-OUT TECHNOLOGY DEVELOPMENT PROJECTS
- DOCUMENT FINDINGS FROM COMPLETED PROGRAMS
- TRANSFER RESEARCH RESULTS TO INDUSTRY

ORGANIZATION



OFFICE OF SOLAR HEAT TECHNOLOGIES

KEY PARTICIPANTS AND ROLES IN FIELD ORGANIZATION



PASSIVE AND HYBRID SOLAR GOALS AND STRATEGY

GOALS:

- ESTABLISH A 30% COST-TO-PERFORMANCE IMPROVEMENT OVER STATE-OF-THE-ART PASSIVE SYSTEM MATERIALS AND COMPONENTS
- DEVELOP SMALL SCALE PASSIVE SYSTEMS FOR RESIDENTIAL BUILDINGS WHICH PROVIDE 60% OF TOTAL BUILDING LOADS AT AN AVERAGE SYSTEM CONSTRUCTION COST OF $100/MMBTU/YR.
- DEVELOP LARGE SCALE PASSIVE SYSTEMS FOR NON-RESIDENTIAL BUILDINGS WHICH PROVIDE 40% OF TOTAL BUILDING LOADS AT $250/MMBTU/YR. AVERAGE SYSTEM CONSTRUCTION COST

STRATEGY:

- SUPPORT HIGH RISK, LONG-RANGE APERTURE AND MATERIALS R&D THAT HAS A HIGH PAY-OFF POTENTIAL
- SUPPORT PROOF-OF-CONCEPT FIELD TESTS OF INTEGRATED PASSIVE AND HYBRID BUILDING SYSTEMS IN CONJUNCTION WITH INDUSTRY, UNIVERSITIES, STATE AND LOCAL GOVERNMENTS, AND OTHER FEDERAL AGENCIES
- GATHER AND ANALYZE BUILDING ENERGY PERFORMANCE DATA FROM TEST FACILITIES AND INSTRUMENTED NON-RESIDENTIAL BUILDINGS
- CONCLUDE DEVELOPMENT OF ANALYTICAL TOOLS FOR PREDICTING PASSIVE SYSTEM PERFORMANCE AND TRANSFER RESEARCH RESULTS TO THE BUILDINGS INDUSTRY.

PASSIVE AND HYBRID SOLAR: PRIOR ACCOMPLISHMENTS

- ESTABLISHED DESIGN FOR FIRST GENERATION RESIDENTIAL HEATING SYSTEMS
  - DEVELOPED ANALYSIS METHODS AND DESIGN TOOLS
  - OVER 50,000 PASSIVE BUILDINGS BUILT AND SOLD
  - PERFORMANCE DATA FROM 40 STRUCTURES COLLECTED/ANALYZED
- CHARACTERIZED POTENTIAL OF PASSIVE COOLING SYSTEMS
  - INITIAL CYCLE OF EXPERIMENTAL BUILDINGS COMPLETED
  - COMPLETED INITIAL QUANTITATIVE DESCRIPTION OF HEAT TRANSFER MECHANICS
- INITIATED FIELD TESTING OF COMMERCIAL BUILDINGS PROTOTYPES
  - ESTABLISHED PERFORMANCE DATA ACQUISITION PROGRAM
  - 7 OF 23 PROTOTYPE BUILDINGS COMPLETED
- ASSISTED PASSIVE COMPONENTS AND MATERIALS DEVELOPMENT
  - HEAT MIRROR GLAZING BEING MANUFACTURED AND COMMERCIALLY AVAILABLE
  - PHASE-CHANGE WALL ASSEMBLY FOR ENERGY STORAGE UNDER TEST

PASSIVE AND HYBRID SOLAR FY 1982 R&D THRUSTS

COLLECTION

- IMPROVE MATERIALS AND SYSTEMS TO REDUCE UNWANTED GAINS OR LOSSES (5% OF TOTAL U.S. ENERGY END-USE OFFSETS APERTURE INEFFICIENCIES)

STORAGE

- DEVELOP/SELECT MATERIALS TO ELIMINATE THE POTENTIAL FOR OVERHEATING AND INCREASE PASSIVE EFFECTIVENESS (ESPECIALLY USEFUL FOR RETROFIT APPLICATIONS)

COOLING

- ESTABLISH PASSIVE COOLING DESIGN BASE AND ANALYZE MULTIZONE INTEGRATED HEATING, COOLING AND DAYLIGHTING SYSTEMS

OFFICE OF SOLAR HEAT TECHNOLOGIES

PASSIVE AND HYBRID SOLAR FY82 ACCOMPLISHMENTS

COLLECTION:

- DEVELOPMENT AND PRODUCTION OF A TRANSPARENT FILM THAT REFLECTS LONG WAVE INFRARED RADIATION
- DEVELOPMENT AND STUDY OF SEVERAL OPTICAL SWITCHING FILMS
- STUDY OF CERTAIN HIGH TRANSMISSION MATERIALS: THEIR OPTICAL PROPERTIES MEASURED AND THEIR THERMAL PROPERTIES CALCULATED

STORAGE:

- IDENTIFICATION OF A NUMBER OF PROMISING PHASE-CHANGE THERMAL STORAGE MATERIALS, INCLUDING ORGANIC SOLID SOLUTIONS OF PENTSERYTHRITOL, PENTAGLYCERINE, AND NEOPENTYL GLYCOL

PASSIVE AND HYBRID SOLAR FY82 ACCOMPLISHMENTS (CON'T)

BUILDING APPLICATIONS:

- CONSTRUCTION AND OCCUPANCY OF 15 BUILDINGS, THAT INCORPORATE PASSIVE HEATING, COOLING AND DAYLIGHTING FEATURES BY THE PASSIVE SOLAR COMMERCIAL EXPERIMENTAL BUILDINGS PROGRAM
- DESIGNS COMPLETED FOR 22 DIFFERENT BUILDINGS AND 8 PROTOTYPE BUILDINGS CONSTRUCTED UNDER THE DIRECTION OF THE PASSIVE AND HYBRID MANUFACTURED BUILDINGS PROGRAM
- DEVELOPMENT OF A UNIFORM TESTING METHODOLOGY AND INSTALLATION OF DATA ACQUISITION HARDWARE ON 63 SITES ACROSS THE NATION BY THE PERFORMANCE MONITORING PROGRAM

COOLING:

- COMPLETED HEAT TRANSFER DESCRIPTIONS FOR COOLING SYSTEMS AND VALIDATED SYSTEM DESIGN METHODS BASED ON TRANSFER DESCRIPTIONS
- COMPLETED COOLING SYSTEMS RESOURCE ASSESSMENT FOR MAJOR CLIMATIC REGIONS

ACTIVE HEATING AND COOLING GOALS AND STRATEGY

GOALS:

- IMPROVE THE PERFORMANCE/COST RATIO OF ACTIVE SPACE CONDITIONING SYSTEMS BY A FACTOR OF TWO TO FOUR
- IMPROVE LONG-TERM SYSTEM PERFORMANCE, RELIABILITY, AND MAINTAINABILITY TO OBTAIN SYSTEMS CAPABLE OF ACHIEVING 20 YEAR SERVICE LIVES

STRATEGY:

- SUPPORT HIGH RISK, LONG-RANGE MATERIALS AND COMPONENTS R&D THAT HAS A HIGH PAY-OFF POTENTIAL
- SUPPORT PROOF-OF-CONCEPT FIELD TESTS OF ADVANCED SYSTEMS IN CONJUNCTION WITH INDUSTRY, UNIVERSITIES, STATE AND LOCAL GOVERNMENTS, AND OTHER FEDERAL AGENCIES
- GATHER AND ANALYZE PERFORMANCE DATA, CONCLUDE DEVELOPMENT OF ANALYTICAL TOOLS, AND PHASE OUT TECHNOLOGY DEVELOPMENT PROJECTS
- DOCUMENT FINDINGS FROM COMPLETED PROGRAMS AND TRANSFER THE RESEARCH RESULTS TO INDUSTRY

ACTIVE HEATING AND COOLING: PRIOR ACCOMPLISHMENTS

- SOLAR HOT WATER INDUSTRY ESTABLISHED
  - OVER 300,000 SYSTEMS IN USE; ESTIMATED SALES OF $325 MILLION IN 1981
  - OVER 60 MAJOR SOLAR EQUIPMENT AND 1,800 INSTALLATION FIRMS IN FIELD
  - PRODUCED AND PUBLISHED DESIGN HANDBOOKS AND VALIDATED DESIGN TOOLS
  - SUPPORTED DEVELOPMENT OF 10,500 RESIDENTIAL, 70 COMMERCIAL, AND 700 FEDERAL HOT WATER SYSTEMS
- SPACE HEATING TECHNOLOGY BASE ESTABLISHED
  - SUPPORTED DEVELOPMENT AND TEST OF OVER 500 SYSTEMS WITH NEW COMPONENTS AND DESIGNS
  - DEVELOPED IMPROVED SELECTIVE SURFACES, LOW COST PLASTIC FILMS, AND MORE EFFICIENT ENERGY STORAGE TO LOWER SYSTEM COST AND INCREASE RELIABILITY
  - TESTED AND REPORTED PERFORMANCE FROM 75 SPACE HEATING SYSTEMS
  - DEVELOPED AND TESTED 4 SOLAR-ASSISTED HEAT PUMPS WITH COPs OF 9-10

920P-13

ACTIVE HEATING AND COOLING: PRIOR ACCOMPLISHMENTS (CON'T)

- SOLAR COOLING SYSTEMS PROTOTYPE DEVELOPMENT COMPLETED
  - FIELD TESTED 3, 10, 25 AND 200 TON COOLING SYSTEMS USING RANKINE AND ABSORPTION DESIGNS -- ACHIEVED STEADY-STATE COPs OF 0.75
  - DEVELOPED PERFORMANCE PREDICTION MODELS; BUILT AND TESTED CLOSED-CYCLE DESICCANT SYSTEM

ACTIVE HEATING AND COOLING FY 1982 R&D THRUSTS

COMPONENTS AND MATERIALS

IMPROVE PERFORMANCE AND RELIABILITY AND LOWER COST OF BASIC MATERIALS AND COMPONENTS OF PRINCIPAL ACTIVE ELEMENTS -- COLLECTORS AND CHILLERS

ADVANCED SYSTEMS

DEVELOP AND TEST ADVANCED SYSTEMS TO ACHIEVE COST COMPETITIVE STATUS FOR ACTIVE SYSTEMS

ANALYSIS AND EVALUATION

VALIDATE SYSTEMS ANALYSIS TOOLS BASED ON ACQUIRED PERFORMANCE DATA FROM STATE-OF-THE-ART SYSTEMS

ACTIVE HEATING AND COOLING FY 1982 ACCOMPLISHMENTS

COMPONENTS AND MATERIALS

- DESIGN AND PRODUCTION OF A PROTOTYPE THIN FILM POLYMER LAMINATE COLLECTOR
- COMPLETION OF THE FIRST PHASE OF DEVELOPMENT OF AN INNOVATIVE HIGH TEMPERATURE AIR-COOLED ABSORPTION CHILLER

ADVANCED SYSTEMS

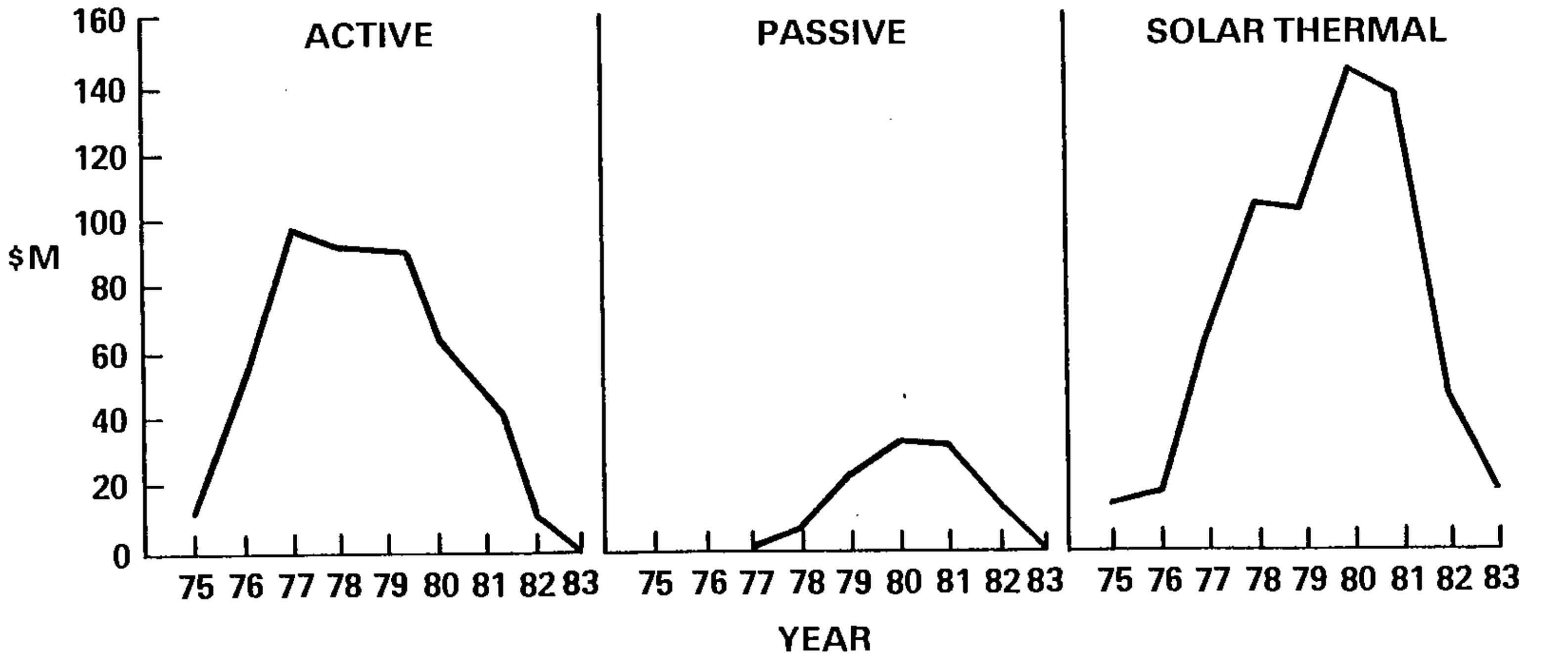
- AWARD OF FOUR CONTRACTS FOR THE DEVELOPMENT OF INNOVATIVE, COST-EFFECTIVE, AND RELIABLE PACKAGED RESIDENTIAL SPACE HEATING SYSTEMS

ANALYSIS AND EVALUATION

- DEVELOPMENT OF CONSENSUS TEST AND EVALUATION PROCEDURES THAT PROVIDE A UNIFORM TECHNICAL BASIS FOR MEASURING THE PERFORMANCE AND ESTABLISHING AN ENGINEERING DATA BASE ON ACTIVE SOLAR HEATING AND COOLINNG SYSTEMS, COMPONENTS, AND MATERIALS
- PREPARATION OF DETAILED RESEARCH REVIEWS FOR EIGHT POTENTIAL MATERIALS RESEARCH AREAS
- COMPLETED AN EVALUATION OF ADVANCED SOLAR HEAT PUMP SYSTEMS WHICH SHOWS THAT SOLAR ASSISTED HEAT PUMPS DO NOT PROVIDE A COST-EFFECTIVE USE OF SOLAR ENERGY

BUDGET HISTORY
(IN MILLIONS)

	1975	1976	1977	1978	1979	1980	1981	1982	1983
ACTIVE	12.5	52.7	97.6	91.3	90.4	65.1	41.4	11.5	6.6
PASSIVE	0.0	0.0	1.4	7.8	23.9	32.9	30.2	11.6	5.0
SOLAR THERMAL	13.2	18.9	65.3	104.1	100.1	143.7	138.3	59.95	47.2



DOE SOLAR HEATING AND COOLING BUDGET FY 1981 AND 1982
($ MILLIONS)

PASSIVE PROGRAM ELEMENTS	FY 81	FY 82
RESIDENTIAL BUILDINGS	$17.0	$ 3.915
NONRESIDENTIAL BUILDINGS	8.7	3.730
MATERIALS & COMPONENTS	2.9.	3.969
SOLAR CITIES & AGRICULTURE	2.1	-
HEADQUARTERS	-	.550
CAPTIAL EQUIPMENT	0.5	.500
TOTAL	$31.2	$12.664

ACTIVE PROGRAM ELEMENTS	FY 81	FY 82
ADVANCED RESEARCH & ANALYSIS		
- COMPONENT RESEARCH	4.80	4.93
- MATERIALS RESEARCH	.90	1.57
SYSTEMS DEVELOPMENT		
- ADVANCED SYSTEM	10.80	1.98
- ANALYSIS & EVALUATION	7.05	2.23
INDUSTRY SUPPORT	16.60	.29
CAPITAL EQUIPMENT	1.25	.50
TOTAL	$41.40	$11.50

INTEGRATED LONG-RANGE HIGH RISK RESEARCH PLANNING

THE OBJECTIVES ARE TO:

- ESTABLISH LONG-TERM GOALS AND OBJECTIVES FOR RESEARCH IN SOLAR HEAT TECHNOLOGIES
- ESTABLISH A PROGRAM STRUCTURE THAT INCLUDES ALL ACTIVITIES NEEDED TO ACHIEVE THESE OBJECTIVES
- PROVIDE A MECHANISM TO SCREEN CANDIDATE RESEARCH ACTIVITIES
- PRIORITIZE THE SUITABLE RESEARCH ACTIVITIES

PRELIMINARY RESEARCH PROGRAM STRUCTURE

MATERIALS

- **OPTICAL MATERIALS**
  - REFLECTORS
  - TRANSMITTERS
- **THERMAL MATERIALS**
  - FLUIDS
  - CONTAINERS
  - ABSORBERS
- **STRUCTURAL MATERIALS**

THERMAL SCIENCE

- **THERMODYNAMICS**
  - CYCLE ANALYSIS
  - PROPERTIES MEASUREMENTS
- **HEAT TRANSFER**
  - BUILDINGS
  - HIGH TEMPERATURE
  - HEAT EXCHANGERS
  - PONDS
  - PROPERTIES MEASUREMENTS
- **OPTICS**
  - RADIATION TRANSPORT
  - RADIATION PROPERTIES

CHEMISTRY

- **FUELS**
  - HYDROGEN PRODUCTION FROM THERMOCHEMICAL DISSOCIATION OF H_2O
  - HYDROGEN PRODUCTION FROM THERMAL DISSOCIATION OF H_2O
  - HYDROGEN PRODUCTION FROM H_2S
  - NON-HYDROGEN FUELS
- **CHEMICAL REACTIONS**
  - THERMOCHEMICAL REACTIONS
  - PHOTOCHEMICAL REACTIONS
- **CHEMICAL**
  - PRODUCTION/PURIFICATION OF HIGH VALUE, HIGH T, METALS
  - PRODUCTION/PURIFICATION OF INORGANIC CHEMICALS
  - PRODUCTION OF ORGANIC CHEMICALS
- **REACTOR RESEARCH**
  - DIRECT HEATED, GAS/SOLID REACTOR (AIR)
  - DIRECT HEATED, GAS/SOLID REACTOR (CONTROLLED ATM.)
  - INDIRECT HEATED, GAS/SOLID REACTOR (AIR OR CONTROLLED ATM.)
  - DIRECT HEATED GAS/GAS REACTOR (AIR OR CONTROLLED ATM.)

ENGINEERING

- **CONCEPT EVALUATION**
- **ANALYSIS**
- **RESEARCH AND DEVELOPMENT**
  - ENGINEERING METHODS AND PROCESSES
  - MATERIALS
  - COMPONENTS
  - SYSTEMS