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Solar-Assisted District Heating

- Solar energy meets 40 - 60 per cent of heating needs in pilot systems with seasonal storage
- Efficiency related to return temperatures in district heating nets
- Increased efficiency expected with low-temperature heating systems

Fig 1

Pilot System in Steinfurt-Borghorst

In recent years, a range of models have been developed to supply energy to housing settlements and reduce fossil fuel use in heating by at least 50 per cent while keeping additional costs at a minimum. Use of solar-thermal energy in district heating is an important component of this supply model.

Solar-assisted district heating is primarily considered in planning for new development areas. From the outset, it is important to have an integral concept that is developed and implemented by all the actors involved and comprises both improved heat insulation in buildings and energy-efficient heat generation and distribution.

Development of this model started in Germany in the early 1990s, with four solar district heating plants featuring short-term heat storage and large-scale collectors. Since 1993, seven pilot systems with long-term heat storage have been developed as part of the Solarthermie 2000 scheme run by the Federal Ministry of Economics and Labour (BMWA). The systems are tested under realistic operating conditions and are evaluated as part of a scientific study. The results of the study serve in analysing and remedying weak points to assist further development of the technology. The main focus of the study is to gain experience with the different storage concepts and large-scale collectors, a reduction in investment costs, operation of a district heating net, and regulation technology. Significant technological advancement is expected with the low-temperature heating systems currently being put into operation. Large solar systems with collector areas greater than 100 m^2 and solar district heating systems with short and long-term heat storage are the most efficient approach to thermal use of solar energy and to reducing CO_2 emissions by forcing reductions in the use of fossil fuels.

System Models

Solar-assisted district heating systems with short-term heat storage can supply between 10 - 20 per cent of the total heat needed to heat rooms and hot water (Fig 2). The goal of solar-assisted district heating with long-term heat storage is the use of solar heat stored in summer to heat rooms in winter. For economic reasons, the pilot projects are equipped to supply between 40 and 60 per cent of the total heat needed to heat rooms and hot water. Figure 3 shows a schematic diagram of a pilot system and a range of options for connecting the system to the district heating net.

Fig 2: Current Plan for Systems with Short-term Heat Storage

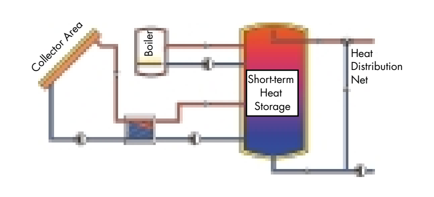
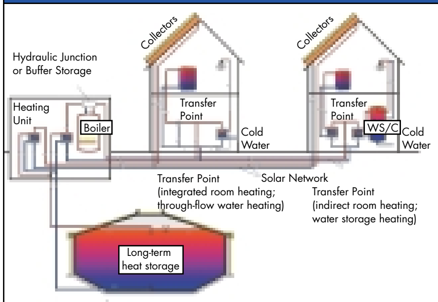


Fig 3: Solar-Assisted District Heat System with Seasonal Heat Storage



(WS: Water Storage, C: Circulation)

Design and Economic Efficiency

Design standards for solar-assisted district heating systems are shown in Fig 4. For purposes of comparison, a small system is shown which only serves water heating. The cited costs of solar heat apply for the German market and show the annualised investment costs needed to save one kWh (basis: market prices in 1997/98 excluding VAT; discount rate: 6%). An accurate consumption profile and detailed simulation calculations are vital in the planning of a seasonal heat storage unit.
The comparison of solar heat costs (Fig 4) shows that the cost-benefit ratio for solar-assisted district heating is greater than that for small systems. This is due to the lower area-related system costs.

Fig 4: Design Standards for Solar-Assisted District Heating

System Type	Small Hot-Water Heating System	Solar District Heating with Short-Term Heat Storage	Solar District Heating with Long-Term Heat Storage
Minimum System Size	-	from 30 - 50 RU or from 60 people	from around 100 RU (each 70 m²)
Collectors	1 - 1.5 m^2_{FC} per person	0.8 - 1.2 m^2_{FC} per person	1.4 - 2.4 m^2_{FC} per MWh Annual heat needs 0.14 to 0.2 m^2_{FC} per m² living space
Storage Volume	50 - 80 l/m^2_{FC}	50 - 100 l/m^2_{FC}	1.4 - 2.1 m^3_w/m^2_{FC}
Solar Utility Energy	350 - 450 $kWh/(m^2_{FC}a)$	350 - 500 $kWh/(m^2_{FC}a)$	230 - 350 $kWh/(m^2_{FC}a)$*
Solar Share of Supply (in new building)	Hot water: 50 - 60%, Total heat: 15%	Hot water: 50%, Total heat: 10 - 20%	Hot water: 40 - 60%,
Solar Heat Costs	30 - 60 Pf/kWh	15 - 30 Pf/kWh	15 - 30 Pf/kWh*

RU: Residential Unit, **FC:** Flat-plate Collector, **w:** Water Equivalent,
*: Values for long-term operation calculated using TRNSYS

Pilot Systems with Long-Term Heat Storage

Four types of storage units have been developed for seasonal heat storage. The decision for a specific type largely depends on the geological and hydrogeological conditions at the chosen site.
The first pilot systems for solar district heat supply with long-term heat storage went into operation in autumn 1996 (Hamburg, Friedrichshafen) and in January 1999 (Neckarsulm). Fig. 5 contains a summary of the typical planning data for the three projects.
Performance results are only available for Friedrichshafen because the metering equipment in Hamburg was badly damaged after being struck by lightning. As expected in the early operating years, above average heat losses to the surrounding earth occurred and high 'heat investment' in achieving operating temperature in the storage unit resulted. An almost constant situation has since been reached in these areas. There were, however, a number of unforeseen problems: the return temperature in the heating system was more than 10 K higher than planned.
This has largely resulted in inadequate compatibility between the building systems and the district heating net. Research is currently underway as to the causes. Division of the project into two construction phases means that only 50 per cent of the planned collector area for full storage capacity has been achieved. Once the second phase is completed, the collector system is expected to go into

Fig 5: Technical Data for Pilot Systems in Hamburg, Friedrichshafen and Neckarsulm

	Hamburg	Friedrichshafen		Neckarsulm II
		Planning	Result 1997 - 1999	
Supply Area	124 SFD	570 RU, in 8 MFD	280 RU and 1Kindergarten Shopping Centre	6 MFD, School, Old People's Home,
Heated Living/ Utility Space in m²	14,800	39,500	21,380	20,000
Solar System				
Collector Area in m²	3,000	5,600	2,800	2,700
Storage Unit Type	Hot Water	Hot Water	Hot Water	Earth Probes
Storage Volume in m³	4,500	12,000	12,000	20,000
Total Heat Needs from Heating Unit in MWh/a	1,610	4,106	2,200 - 2,300	1,663
Utility Heat Supply Solar System in MWh/a	789*	1,915	475 - 620	832*
Solar Share of Supply %	49*	47*	21 - 28	50*
Costs Solar System in DM million	4.3	6.3	4.8	2.9
Solar Heat Price in Pf/kWh (excl. subsidy, excl. VAT, incl. planning)	50.2	31.1		33.7

MFD: Multi-family Dwelling, **SFD:** Single-family Dwelling, **RU:** Residential Unit
*: Values for long-term operation calculated using TRNSYS

operation in autumn 2001 and will then be better equipped to achieve performance as planned.

A three-pipe network was installed in Neckarsulm: in the buildings, return heat is fed back into the collectors for district heat supply. This does away with the need for the system to have its own return pipe between the heating plant and the collectors.

The solar-assisted districted heating system in Steinfurt (Fig 6) supplies just 42 residential units. The buildings in Steinfurt are fitted with underfloor heating and a hot-water heating system that operates on the through-flow principle, whereby low operating temperatures are achieved in the heat distribution net. If higher temperatures are needed to heat hot water, they are achieved through re-heating in the buildings themselves.

The first solar-assisted districting heating plant in Rostock went into operation at the end of 1999. It uses aquifer heat storage. The system supplies a large multi-family dwelling of 108 residential units. To distribute heat, a low-temperature heating system (50/30 °C) with radiators was developed to achieve low return temperatures and thus good operational conditions for the solar system.

Fig 6: Technical Data for Pilot Systems in Hamburg, Friedrichshafen and Neckarsulm

	Steinfurt	Chemnitz[1] 1. CP	Rostock[2]	Hannover[3]
Supply Area	42 RU in 15 SFD and 7MFD	Office Building	108 RU in MFD	106 RU
Heated Living/Utility Space in m^2	3,800	4,680	7,000	7,365
Solar System Collector Surface in m^2	510	540 VT	1,000	1,350
Storage Type	Gravel/ Water	Gravel/ Water	Aquifer	Hot Water
Storage Volume in m^3	1,500	8,000	20,000	2,750
Total Heat Demand from Heating Unitin in MWh/a	325	1. CP: 573	497	694
Utility Heat Supply Solar System in MWh/a	110	1. CP: 169	307	269
Solar Share in Supply in %*	34	1. CP: 30	62	39
Costs Solar System in DM millions	1.0	1. + 2. CP: 2.8	1.4	2.4
Solar Heat Price in Pf/kWh (excl. subsidy, excl. VAT, incl. planning)	82.8	1. + 2. CP: 47	49.9	81

SFD: Single-family Dwelling, **MFD:** Multi-family Dwelling, **RU:** Residential Unit, **VT:** Vacuum Tube Collector, **CP:** Construction Phase, **1.** Data TU Chemnitz, **2.** Data GTN, Neubrandenburg, **3.** Data, University of Braunschweig, *: Values for long-term operation calculated using TRNSYS

Results and Experience

While the first pilot projects using short-term heat storage often involved collectors placed on newly-built roofs, they are now integrated into the roof structure. The latest systems have solar roofs in which the absorption panels are integrated into a pre-constructed roof element. The most modern solar roof, with integrated roof windows and hidden elements, is installed on the roof of the Helios building in Rostock (Fig 8). All the collectors – including those in the solar roofs – are back ventilated to allow diffunding moisture under the collectors to escape. The safety standards for large-scale collectors have been regulated through their inclusion in the Steam Boiler Ordinance (Dampfkesselverordnung).

Heating System and Hot-Water Heater

The heating system design and the type of hot-water heating is determined by the return temperature in the district heating net and thus by the amount of solar utility heat yielded. Compared with conventional heating systems, low-temperature heating systems can achieve lower return temperatures and higher yields of solar utility heat. Because the development of low-temperature heating systems involves higher costs, much depends on the efforts of builders and planners. The Helios project in Rostock shows that low-temperature heating systems are possible even in a block of rental apartments.

A hot-water heating system with a tankless water heater usually achieves lower network return temperatures than storage tank systems (Fig 3). The latter type is, however, the one usually used in large multi-family dwellings. Because of the need to heat the return in the water system, these systems can achieve average network return temperatures of between 50 °C and 55 °C. Experience has shown that lower temperatures can only be achieved in pilot systems if the heat exchanger in each individual building is improved to achieve the lowest possible return temperature to the net.

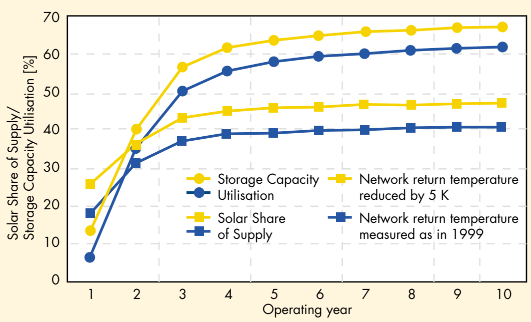
Heat Exchangers

Each heat exchanger increases the return temperature by up to 5 K due to the temperature differences that occur in heat exchange. For this reason, preference should be given to a room heating system that is directly connected to district heat supply rather than one that is indirectly connected (Fig 3). In the pilot systems, direct integration of heating systems cannot be implemented in all cases because the operators of the district heating net wish to separate their net from the house net by means of a heat exchanger.

The influence of the net return temperature on the solar share of supply is considerable. Fig 7 shows a prognosis of the solar share of supply for the pilot systems in Neckarsulm. Due to the initial need for a heating up phase for the long-term heat storage unit, constant operating conditions could only be achieved after 5 to 6 operating years. If the net return temperature can be reduced by 5 K to an average 40 °C, the solar share of supply rises by an absolute 7 per cent and the planned solar share of supply of 50 per cent is almost fully achieved. The most common defect in conventional house systems identified by the supporting metering work are hot-water and room heating systems that have not been hydraulically aligned, plate heat exchangers with inadequate exchange performance and regulation problems in heating systems that are regulated by outside temperatures.

The influence that district heating providers have on household systems is extremely limited because district heating systems end at the point where they meet the building's heat exchanger. Achieving the lowest possible net return temperature to achieve the highest possible yield of solar utility heat can only be effected by means of constant project monitoring that integrates and incentivises all those involved in the project, and especially the companies carrying out the work.

Fig 7: Prognosis of the Solar Share of Supply and Storage Capacity Utilisation for the Pilot Systems in Neckarsulm (Basis: Measured Values 1999)



▶ Outlook

The technology used in solar district heating is still in the development and testing phase. At least one pilot project is under way for each of the four storage models. The first projects have confirmed the basic approach: existing weak points were analysed to prevent them occurring in projects about to start. Up to now, the high investment costs for operators and investors has been the major obstacle in expanding the use of solar-assisted district heating systems. The projects already implemented have shown that that obstacle can be overcome with innovative funding models. Further cost savings can be made with further development of the system technology.
A new study has shown that further improvement on the 20 per cent reduction in annual heat consumption prescribed in the 1995 Heat Conservation Ordinance (WschVO 95) would allow large solar systems to compete with other energy-saving measures like additional heat recovery plants. The new Energy Conservation Ordinance (EnEV) is expected to bring about energy savings in the range of 20 - 30 per cent.

Fig 8: 1000 m^2 Solar Roof; North-south multi-family dwelling (Rostock)

For solar-assisted district heating with long-term heat storage, the aim in the coming years is to have non-subsidised solar heat prices that are no more than double the current price for conventional heating. Solar-assisted district heating systems with short-term heat storage and a solar share of supply of between 7 and 10 per cent of total heat demand are already nearing commercial viability.
It thus makes sense in the development and planning of new housing areas, to assess the conditions for a solar-assisted district heating supply with short-term heat storage. One alternative is district heating supply with combined solar and biomass energy (woodchips). The first pilots projects of this type are currently in the planning and construction stage as part of the Solarthermie-2000 scheme. Given the significantly higher solar heat costs with a solar district heating supply with long-term heat storage, this is one future-focused option that has considerably greater potential for conserving fossil fuels.

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Literature
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Service
- A comprehensive list of subject-related literature and a list of contact addresses for the various projects are available [in German] at www.bine.info (click on 'Service/InfoPlus').

  Further information is also available [in German] at http://www.solarthermie2000.de

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