Solar Settlement
Freiburg, Germany

PROJECT SUMMARY

In the south of the City Freiburg (200.000 inhabitants), located in the South-West corner of Germany, a new district (42 ha) is being developed for 5,000 inhabitants and will be completed in 2006. The new district is called **"Quartier Vauban"** after a French army barrack site on the same place, that was abandoned in 1992.

The Project **"Solar Settlement in Freiburg"** aims to erect six buildings with altogether 90 units for mixed use (ca. 80% housing, 20% workspace) in the North-Western corner of Quartier Vauban. The six multifamily houses will provide four storeys plus basement and will be of compact shape and in good exposition to the sun.

The aims of the development are to provide housing with a minimum of energy demand for heating, high living quality and fitting best into the neighbourhood and given infrastructure - while at the same time minimising the extra costs in relation to standard buildings to a minimum.
A team of architects and engineers, specialised on modelling low energy houses and solar gains, has been invited by a group of private investors to plan the six buildings.

On the following pages, these aims as well as the given circumstances are explained. The process of selecting alternative measures to reach the objectives will be described, with a special emphasis on the cost-benefit considerations in the area of insulation, heat generation and the design of the planned buildings.

SUMMARY STATISTICS

Location: Freiburg, SW Germany, 48°N, 7°E.
Project: Six multi family houses, 90 units (80% housing, 20% workspace)
Aims: Minimised energy demand, highest comfort, extra costs < 10%
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- Developer, Architects, Author of the Case Study:
C/O Forum Vauban e.V., Mr. J. Lange and Mr. P. Spaeth, ...

THE SITE

The City of Freiburg is a main centre (university, little industry, mainly services) in South-West Germany, near the border to France and Sitzerland. It is surrounded by the Black Forest Slopes and opens to the plain of the Upper Rhine Valley.

Background

By the drastic historic changes of the year 1990 the City of Freiburg out of a sudden got property of the area of the French Army barracks which had been closed for the German public for more than four decades. Consequently, there was a strong public focus on the development of this new space in the city centre. Quickly a consensus was reached between the local decision makers and the public that the unique occasion of the district Vauban is to be used for creating truly innovative living and working structures. The idea of a "sustainable model city district" was born.

The target residents for the model city district are young families with academic background with considerable economic back-ground. Particular emphasis is given to create space also for other specific social groups like students and underprivileged groups.
The Quartier Vauban is urban and characterised by high density of 110 inhabitants per ha.

The area is on the urban fringe, flat and in close proximity of the Black Forest mountains. The surrounding hills are covered partly with high income housing, but mainly with pasture, arable land, vinejards and forest. On the inclined open land uphill the site, cold air is produced which streams down into the site – a comfortable effect in hot summer evenings. In winter evenings, the site is occasionally shaded by the nearest Peak (Schönberg, 645 m.a.s.l.).

The local climate is very moderate: The sun shines more than 1800 h/a; with a global radiation of 1100 kWh/m² *a. Wind blows with 2,7 m/s (all year average) and the average Temperature is 10,3 °C (all year average).

PROJECT DESCRIPTION

In consequence with the overall idea of a sustainable model city district, the building project "Solar Settlement Freiburg" follows the vision of a sustainability which is understood as social and environmental innovation.

The future inhabitants form a construction association which is jointly planning and implementing the project. A draft for the architectural design and a project plan has been developed.

The project is aiming to integrate
a) a maximum in reduction of CO_2 Emissions (80% compared to standard buildings)
b) with highest cost effectiveness (less than 10% additional costs (average + max. 150 Euro/ sqm)

A profound cost benefit analysis helps to define the most cost effective ways of CO2 reduction – i.e. measures that have a pay back time of less than 20 years.

To reach the CO_2 reduction targets, various innovative modules are combined, namely:

- **Optimised building envelope:** Building in Passive House Standard with a heating demand of less than 15 kWh/m²*a; optimised design concerning shading in summer and daylight in the building.
- **Very detailed planning:** and measurement programme to reduce heat leakage, extra insulation of tubes to reduce heat allocation losses.
- **Active use of solar Energy:** Solar thermal plant (46 m²) for hot water (100% in summer) Building integrated PV devices (combining shading, shelter and electricity production).
- **Innovative heating system:** Air conditioning with heat recoverage (80%), Provision of the remaining heat demand with a decentralised CHP device (natural gas).
- **Additional measures:** Combined set-up of living and working space reducing the mobility need of the residents

This overall set-up will bring an 80 % of reduction to common standard in the categories: energy demand for heating, hot water and electricity within the given financial framework (less than 10% additional costs).

The building design prefers a compact shape with high flexibility for the individual room set-up in every storey. With 4-floors plus basement and more then 14.000 square meters of heated floor area the buildings are comparatively large.

In order to meet the ambitious objectives, a special planning framework is needed, including

• **Analysis of local climate conditions**

• Early intervention for the **preservation of the natural on-site ventilation and conservation of old trees**

• Town planning explicitly **reducing individual traffic in the neighbourhood**

Very important:
- An integrated and systematic approach has to be applied and cost benefit analysis' are obligatory in each decision.
- Only careful monitoring and optimising within operation will ensure that the ambitious energy targets will be met.

Additionally, the planning process must adopt to some specifically restricting features of the project site:

- The project has to fill gaps between the existing housing structure of old barrack buildings (3 storeys high, covering 50 by 15 m) for providing the legal necessity for a high living density

THE BASE CASE

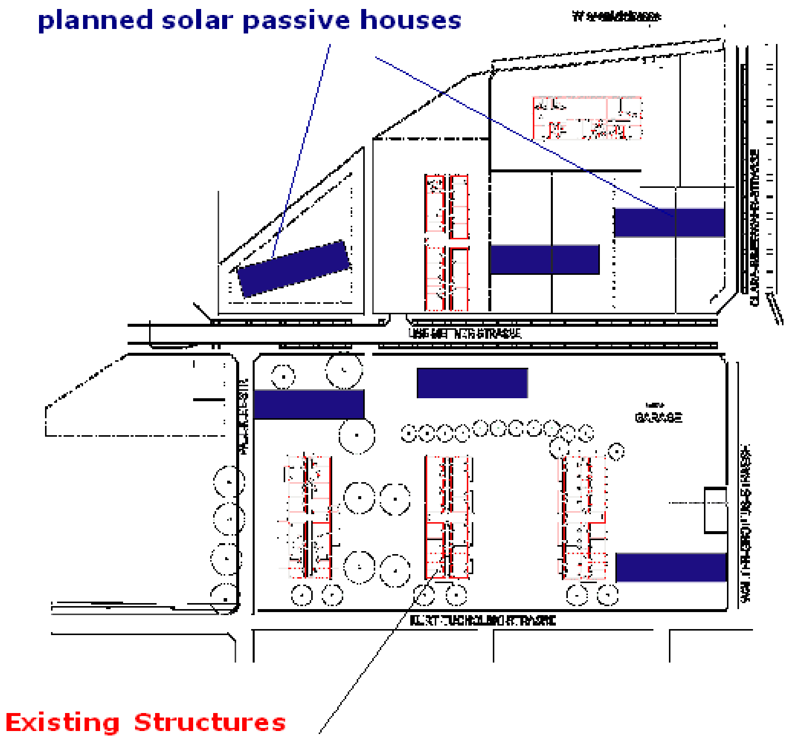
DESCRIPTION OF THE SETTLEMENT

The Project **"Solar Settlement in Freiburg"** aims to erect six buildings with altogether 90 units for mixed use (ca. 80% housing, 20% workspace) in the North-Western corner of Quartier Vauban. The six multifamily houses will provide four storeys plus basement and will be of compact shape (about 45 by 10 m) and in good exposition to the sun (about 15° deviation from ideal south orientation).
The land needed for the "new solar settlement in Freiburg" is currently owned by the City of Freiburg which is also responsible for the overall planning and development of the district. It is going to be sold to private owners and cooperatives in 2003. The project site is flat.

Already existing structures on the project site have to be preserved: Five barrack buildings with three storeys, covering an area of approx. 50 by 15 m. Some old trees (greening in summer, up to 10 m high, 4 m in diameter) are scattered on the site and have to be preserved.

To reduce shading from the existing structures and trees, the six new buildings are each individually situated as far north from other structures as possible. The orientation of one of the buildings has to be adjusted according to a railway line and pathways bordering the site. The resulting declination from ideal south orientation is about 20° - which has been found not to be crucial for the energetic decisions.

One local road (30 km/h) is crossing the area under concern and provides access to the buildings. No space for car parking will be provided, except in the nearby neighbourhood garage. The next large street with more than 10,000 cars per day is found about 100 m east of the site.



INFRA STRUCTURE

There is a city wide district heating system serving nearby houses. The buildings of the "solar settlement Freiburg" will not be connected to this system. Their minimal heat demand will be provided by decentral plants using highly efficient CHP technology. This will be more cost efficient and also reduce the consumption of primary energy.

In respect to the German climate no district cooling network is appropriate, and usually no special means for air conditioning are applied.
Big summer-green trees can provide comfortable shading for passive houses.

The sewage system is relying on maximising the possibilities for natural sickering - by reducing "sealed" areas. The reduction of such "sealed" areas (surface unpermeable for rainwater because of tar etc.) will be realised through town planning regulation and economic incentives guter Absatz!
The ambitious aim with the development of the whole settlement is to reduce the presence of cars in order to achieve a maximum in quality of life for all inhabitants, especially elderly persons and children.

One local road (30 km/h) is crossing the are under concern and provides access to the buildings. The next large street with more than 10.000 cars per day is found about 100 m East of the site.

The town planning of the area has put special emphasis on the reduction of traffic by bringing services and working places close to the people ("district of short distances").
In order to succeed in supplementing car traffic, a maximum of public transport is provided. At the moment, three lines of busses are serving the area. An additional tram line is planned to be finished in the year 2006.
No space for car parking will be provided, except in the multi-storey car park next to the site.

BUILDING DESCRIPTION

The current building standards in Germany are relatively strict. In 1994, the energy demand has been limited by law to 65 kWh/m^2*a.
This level is usually met by a standard insulation (one layer of about 6 cm of cheap mineral fibre on the outer surface of the building; k=0,685 W/^{2}K, 10 cm under the roof; k=0,34 W/m^2K) and through the reduction of uncontrolled ventilation.

The most common materials are massive stones or pre-fabricated concrete. Our imaginative base-case-building is build of massive stones, 24 cm (supporting walls), of pre-fabricated wood panels (non-supporting outer walls), and of pre-fabricated concrete ceilings.

Windows are two layers, Argon (U- Value 1,4, g= 0,58). The houses were connected to a usual district heating system.

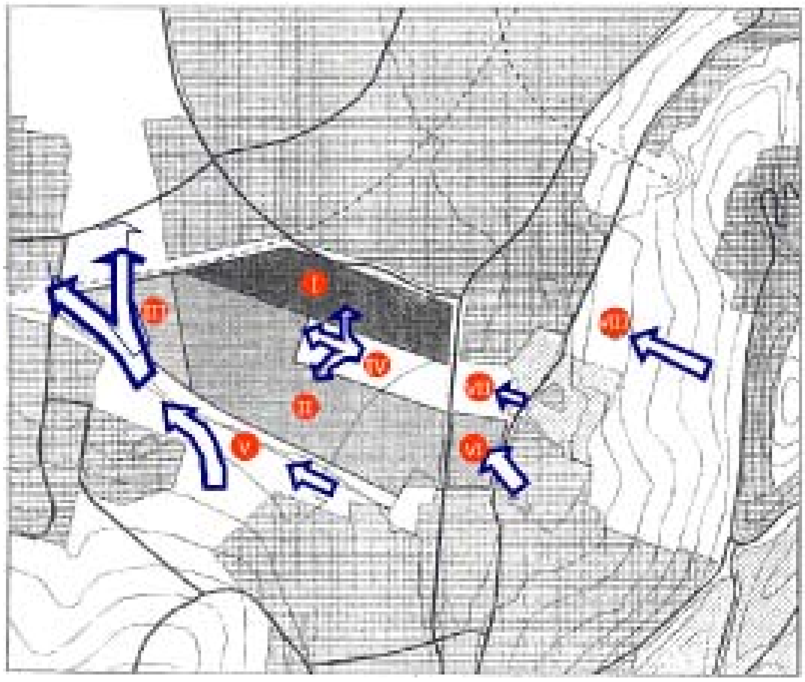
Our imaginary standard buildings would be in accordance with the prevailing idea in the district of a very compact shape, to reduce energy losses and to allow high living density (e.g. no indoor stairs, flat facades without bays etc.)

They have an area of heated floor space of about 1400 m^2. The energy consumption would be just below 65 kWh/m^2*a. Radiators would deliver the heat individually to the rooms. No means for cooling in summer would be applied.

Pumps would cause remarkable building related electricity consumption (about 440 kWh/ houshold*a). The average individual electricity consumption of a four persons houshold in Germany is about 4.0000 kWh/a.

Such houses are built in the nearest neighbourhood of the site, e.g. in the year 2001.

SCENARIO



[map of main wind corridors in the district]

MICROCLIMATE

To improve the microclimate it is important to preserve the existing big trees. For this reason, the layout of the new district has to accept the main orientations of the former barrack sites.

Besides their aesthetic role, the big summer green trees also provide fresh air and can shade the big south facades in summer. The planting of more summer-green trees will further enhance the vegetation's capacity to produce fresh air. At the same time, summer green trees do not disturb the harvest of solar gains in winter.

The layout of the district has also to take into consideration the local wind system. Barriers to the frequent streams of cold air, which are emerging on the declined slopes of open land uphill the site , have to be reduced to a minimum, since these streams of cold air fulfil an important role in cooling down the buildings after hot summer days. These considerations concerning the orientation of buildings have to be weighed up with the solar gains that can be realised with facades oriented towards south.

Further on, the district planning can minimise the sealing (tarring) of surfaces. With economic incentives a municipality can reduce the sealed area. In Freiburg, sewage duties are related to the portion of surface of a plot of land, that is sealed. The city sells land to developers only, if they accept the obligation to have vegetation on the rooftops. The only exception to this obligation are roofs that serve the use of solar energy.

The layout of the buildings themselves has to take into consideration, that streams of air should be enabled to cross the whole building within one flat, with windows to be opened in summer on two opposite facades.

BUILDING ENVELOPE

The building envelopes will be characterised by the following features:

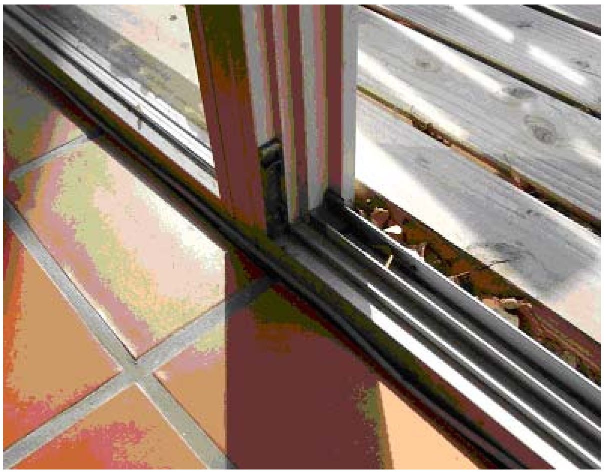
Improved insulation:
- outer (supportive) walls made from bricks with 24 cm (mineral fibre) insulation U= 1,23.
- outer (non-supportive) walls as prefabricated wooden panels with U= 1,23 to 1,65 W/m²*K.
- Windows: three layers, krypton, U= 0,7, g= 0,6 W/m²*K. Roof: 43 cm with 30 cm mineral fibre, thickness with all layers including soil: 58 cm U= 0,1.

Reduction of air leakage:
- air leakage shall be reduced to less than 0,5 h^{-1} at a 50 Pa of extra pressure, by most detailed planning, early blower door measuring and tight co-ordination of all planners and craftsmen.

Innovative heating system (for winter):
- permanent central ventilation (0,4 1/h) with a high heat recoverage rate of 82% by (0,4 1/h, 650 W/building) - bringing down the annual energy demand from 32,7 to 12 kWh/m²a.
- heat generation in highly efficient small CHP-units (15 kW/building) running on natural gas with exhaust pipe heat recoverage (system efficiency of 98%). Overproduction of electricity will be fed into the public grid, and purchased by the electricity provider on the legal basis of the German feed-in law for micro CHP plants.
- heating (10,2 W/m²) with radiators (to provide most comfortable heat, according to individual demand).
- reduced allocation losses by insulation of hot water tubes (double the diameter) in the basement and reduction in tube length.

Passive solar heating

Use of passive solar technologies:
- South facades with 50% glass openings (3 layer insulation glass, Krypton, U=0,7 (incl. frame); g= 0,6 W/m²*K)
- Reduced openings towards north (same type of glazing).

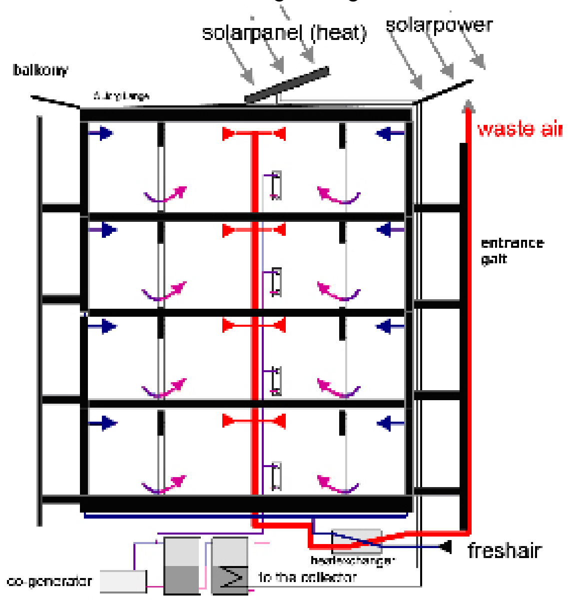


[Photo of three panned window]

Passive cooling and ventilation techniques

The massive building style with brick walls (24 cm) and the good insulation reduces the heating up of the buildings in summer.
Balconies will be shading the south facade. Given the specific conditions of the site and the buildings, they need to be 80 cm large as a minimum.
For the top floor, other shading devices need to be applied: roller blinds, umbrellas etc.

Cross flow ventilation is possible since every flat borders both, the south and the north facade, with the width of the building being about 11 m.



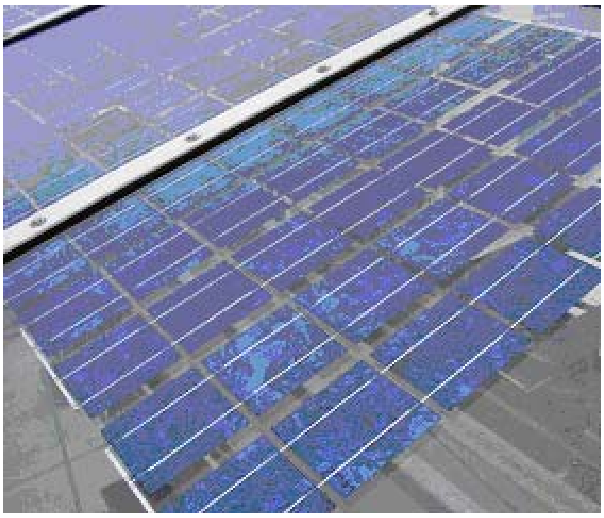
RENEWABLE ENERGY TECHNIQUES

Active solar systems

Active solar systems will be applied:

- A solar thermal plant of 46 m^2 of heat pipe collectors per building will be able to harvest 28% of the heat demand. Storage volume should be 3.600 l. 100% coverage of the heat demand is realistic from mid April till September. Enough space on the table-rooftops has to be provided. According to the municipal ground selling policy, greening of the rooftop is not obligatory for those areas of the roof, which support active solar applications.
- An integrated PV System can provide shelter, shading and electricity at the same time. If the shelter of the gangway of the top floor is made from glass-glass PV -modules it can be transparent and have a peak capacity 3,3 kW_p at the same time.

The CHP unit can easily be replaced by one running on bio-fuels, in case of increasing prices for natural gas and/or to further reduce CO_2-emissions.



[Photo of transparent PV modules (shelter, shading, electricity)]

[Photo/ Schema Ventilation

DEMAND SIDE MANAGEMENT

In passive houses, consistent management and user behaviour is crucial. The system takes this into consideration by applying the following features:

The radiators allow heat control according to individual needs – a central reason for their application in houses with a mixture of flats and offices.

The central ventilation system is running al winter permanently.
Winter mode (below 15°C outdoor temperature or manually): Air input = Air output = 1.450 m^3/h.
Summer mode: Used Air disposal of 1.000 m^3/h.
The air heater of the system is only for cases of emergency and can also be removed to save electricity.
With an increase of the speed in the air-tubes, heat losses can drastically be reduced.

The CHP unit is running according to heat demand, producing electricity only as a spin off.

The radiators (one in every second room) are run only during daytime (6.00 to 22.00 h) on 70°C.

To reduce the consumption of electricity, energy efficient household appliances are promoted among the users. They are informed about opportunities to reduce their private consumption. Dish washers and washing machines are connected to hot water taps. A communal room for drying the washing is provided. Deep-freezers are located in the low-tempered basement. Computing and communication facilities are in general under individual control. They can be offered in a centralised manner house by each house though, which involves opportunities to save a big share of electricity consumption (e.g. stand-by) and to reduce the probability of overheating in summer.

To mix spaces for living and working in the same houses is a means to reduce home-to-work traffic to a minimum.

[Photo of a small CHP unit. 17 kW_{th}]

DISTRICT HEATING AND COOLING SYSTEMS

The buildings will not be connected to the city wide heating network.
Their heat supply will be provided by hot water from solar thermal heat pipes and the "waste" heat of the CHP unit in one system. Radiators are used to cover the little energy demand, left from good insulation and heat recovery of the ventilation system.
Payments for the feeding in of the CHP-unit's electricity production will balance relevant parts of the gas bill. Since the CHP unit is more efficient than the city wide heat network, the balance of primary energy consumption is in favour of this decentralised system. If the city wide heat network would rely on renewable energy to a greater extend or if it improved its efficiency, the connection of the buildings to the network would be advisable.

The small CHP- units can be shared by two or three houses, in order to reduce the costs of maintenance, if this is economically feasible due to low costs for the local heat network. In this case, the solar thermal plants should also be connected.

OTHER RES TECHNOLOGIES

Natural gas for cooking is provided.
The sewage system is optionally able to integrate a biogas-unit, which would process the sewage produced in the building to bio-gas, that can be used for heating (CHP-unit) and for cooking.

In the future, the CHP-unit could be run on biu-fuels.

ENVIRONMENTAL IMPROVEMENTS/ SUSTAINABLE BUILDING

The cables using PVC inflammables are to be avoided. The building material is selected to reduce the inherent "grey" energy, e.g. wooden panels are prefered to bricks and the use of (energy intensive concrete is reduced to a minimum.
Floors are made from natural and unsealed wood.

The sewage system is designed to separate liquid and solid waste from the relatively pure waste water. Therefore a system of vacuum toilets with very little flushing water is applied.

SOCIAL IMPROVEMENTS

In order to provide living and working space which is affordable to a broad spectrum of people, a maximum use of the ground (high ground prices) with compact buildings is necessary.

Cost effectiveness in all measures (max. 10 % additional cost) shall provide an opportunity to middle income people to live and work in an very innovative building.

PROJECT ORGANISATION AND PROJECT MANAGEMENT

In this project, the future inhabitants form an ad-hoc building association and share in the planing on an equal basis. Every participant, future owner or lendor, can contribute to the decisionmaking. The group of associees elect some representatives to manage the day-to-day work in the planning and building phase. Their future flats or offices can be designed individually.

EVALUATION

Due to national legislation, the energy consumption for heating and hot water is limited to 65 kWh/m^2. This would mean for one building of the envisaged size (1400m^2) a consumption of 91 MWh/a. This is equivalent to an emission of xx t of CO2. A building of this size and conventional features would cost xxx •.

LESSONS LEARNED - RECOMMENDATIONS

The envisaged measures can decrease the CO_2-emissions related to heating and hot water by 73%. Would the additional electricity demand stay the same, electricity generation would be responsible for 50 % of the total emissions. The reduction of the total CO_2-emissions would than be 64% in relation to today's average. The project aims to reduce the annual electricity demand from usual 1.100 kWh/person to less than 400 kWh/person.
With these combined efforts, the reduction target of 80% of the total emissions (heat, hot water and electricity) can be met.

The additional cost for these measures are with 10% affordable to wide circles of the population. Within the time span of the buildings the saving in energy and water will more than compensate for these extra costs.