

Optimisation of Solar Energy Use in Large Buildings

TO PROVIDE KNOWLEDGE ON SOLAR ENERGY USE IN LARGE BUILDINGS, 21 BUILDINGS DESIGNED USING THE "WHOLE BUILDING APPROACH" HAVE BEEN EVALUATED AND DOCUMENTED. BOTH THE PARTICULAR PROCESSES USED IN THE DESIGN OF THE BUILDINGS AND THE RESULTING BUILDING PERFORMANCES ARE EVALUATED. THE RESULTS ARE DOCUMENTED IN A REPORT FROM THE IEA SH&C TASK 23.

Background

Within the International Energy Agency (IEA) a comprehensive program of energy co-operation is carried out among the member countries. The Solar Heating and Cooling Implementing Agreement was one of the first collaborative R&D programs to be established within the IEA, and, since 1977, its participants have been conducting a variety of joint projects in active solar, passive solar and photovoltaic technologies, primarily for building applications.

Task 23

In the framework of the IEA Solar Heating & Cooling Programme, "Task 23, Optimisation of Solar Energy Use in Large Buildings" was initiated. The Operating Agent of the Task is Professor Anne Grete Hestnes, Norway.

To significantly reduce the total energy use in large buildings, it is necessary to use several technologies such as energy conservation, daylighting, passive solar, active solar and photovoltaics in combination. The designers of these buildings therefore need to find the optimum combinations of technologies for each specific case. This requires an integrated design approach, where the different low energy and solar technologies to be used are considered integral parts of the whole, also taking architectural quality and functionality into account.

The objective of Task 23 is to enable the designers to realise such integrated design processes and to carry out the necessary optimisation exercises, thereby ensuring the most appropriate use of solar energy in each building project. Providing the designers with design process guidelines and a set of design tools will do this. At the same time, the Task will ensure that the buildings designed using these tools promote sustainable development. Including criteria such as general resource use and local and global environmental impact in the analyses facilitated will do this.

Evaluation and documentation of buildings

In a part of Task 23, "Subtask A, Case Stories", different low energy solar buildings are investigated and documented. The objective of Subtask A is to provide the knowledge needed for guidelines, methods and tools, which will be developed in other subtasks. This was done by evaluating and documenting a set of buildings designed using the "whole building approach". Both the processes used in the design of the buildings and the resulting building performance were evaluated.

The results of these studies have been documented in the report "Description of Case Stories". 21 different solar buildings from 12 different countries, comprising offices, schools, and conference and research centres are presented. The buildings use a number of low energy and solar techniques, including daylighting, passive and active solar systems and photovoltaics. The countries involved are Austria, Canada, Denmark, Finland, Germany, Japan, Korea, Netherlands, Norway, Spain, Sweden, Switzerland and USA.

Examples of Solar Buildings

Primary School, Austria

The primary goal was a building as ecological as possible within a budget only 10% more than usual. This resulted among other things in cork as insulation material, PVC was not used at all and wood was widely used. Prismatic plates serve as shading for direct sunlight, and mirrored shutters reduce glare and direct diffuse light on to the reflective ceiling. Thereby use of daylight is possible.

Today the building serves an example of a school with a very good performance compared to other schools, the occupants are very satisfied and the children highly motivated.

A lesson learned during the design process was that a very close co-operation between architects and engineers from the beginning of the process was necessary to achieve good results. However, a whole building approach also implied problems: each of the planning experts involved aimed at a different goal, a specific goal according to a specific function. It turned out that a guideline was needed on how to deal with these conflicts at the very beginning of the design process.

Office building, Germany

The client wished a building, which further the co-operative aspects of work like communication, discussion, relaxation etc. without hierarchy. Since the company is a software developer, the computer workplaces needed special solutions against glare. Some other important criteria were maximised use of natural daylight, minimised cooling load, low electrical and heating energy use. Furthermore, the building costs and the running costs should be low. To be able to fulfil the wishes from the client it turned out that a close co-operation between architect, client, structural engineer, building services engineer, building physicist was absolutely mandatory. And a personal engagement of the client was necessary to decide innovative solutions, sometimes out of the current norms and regulations.

It was the basic idea to give components of the building several functions. For example to use the central atrium as well as the floor integrated ducts for air-conduction and therefore reduce costs. The round form of the building with a consequent buffering of the heated rooms by a temporal heated yard atrium led to minimise the external building surface, which resulted in reduced heat loss and running costs as well as reduced investment costs for the facade. Pre-cooling by foundation channels and activation of thermal mass through open ceilings replaced a mechanical cooling device. A lesson learned during the design process was, that validation of the concept by dynamic simulation was necessary for forecasting and guarantying temperature profiles, energy consumption for heating, cooling, electricity and comfort level both thermal and visual.

Environmental Science Institute, Japan

Environment-conscious and energy-efficient design and construction was an important start-point as to confirm the owner’s and occupant’s identity. Yamanashi Prefecture Government as owner

wished the building to be a model case of environmental conscious buildings, because the building is used for environmental science learning centre for pupils and research centre on relationship between human and nature from a global viewpoint. The scope of the building has been widely acknowledged and it serves a model of environment-conscious activities for people of the Yamanashi prefecture and others.

Energy saving target was set to reduce total energy consumption by 30% compared to a typical laboratory building. This has been reached by the installation of different solar and low energy techniques such as PV panels, solar air hybrid collectors, heat pumps etc.

Office and conference centre, Denmark

The background for the building is twofold. The technical concept and design idea was based on the winning proposal of the design team for the EU competition "Working in the city". Furthermore, the client of the building was looking for an outstanding building demonstrating the technical and design solutions to achieve a 50% reduction in energy consumption. This reduction was a result of the recommendations from the UN report "Our Common Future".

The design process of the building has in all phases of the project focused on the aim of the project: Demonstration of major energy savings in a new non-domestic building, involving all professions within the building design team. The energy saving measures include, among others, building integrated PV-systems, daylighting techniques and passive solar. A very close co-operation was achieved between the engineers and the architects, which has proved to be a very positive experience for all parts.

A lesson learned was the importance of very close collaboration between the members of the design team. Even though the design team had a good level of communication a number of problems turned out to be unsolved at the time of construction start and had to be solved quickly.

The report is available

The report contains information on the design teams, buildings, mechanical and electrical parameters and the different technologies and energy saving features used. This information is given for each of the 21 buildings. Furthermore, information on the design process is included. This part contains a summary description of the design process (planning, decisions and organisation), description and motivation for the technical and architectural phenomena that have been investigated and an overview of the resources used.

The report is available from

Esbensen Consulting Engineers A/S
att. Christina Henriksen
Vesterbrogade 124 B, DK-1620 Copenhagen V
Phone: + 45 33 26 73 00
Fax: + 45 33 26 73 01
e-mail: c.henriksen@esbensen.dk

The price is 150 DKK incl. postage excl. VAT.

The Danish Energy Agency has financed the editing and publication of the report.

Case Story no. 1:

Primary School, Münchendorf, Austria

Further information:
Susanne Geissler
Austrian Ecology Institute
Seidengasse 13
A-1070 Wien
Phone: +43 1 523 6105-16
Fax: +43 1 523 5843

0. Overall

0.1 Name of building	Primary School Münchendorf Sportplatzstraße, A-2482 Münchendorf
0.2 Type of building	primary school
0.3 Owner / Operator	local authorities of Münchendorf (in Lower Austria near Vienna)
0.4 Construction	December 1993 - March 1995
0.5 Planning time	August 1992 - March 3rd 1993 negotiation with the building authority to receive the building permit March 3rd 1993 - December 1993
0.6 Building costs	total: 30 263 000 ATS (2 277 000 USD) net cost of construction, no property, no design cost included per m^2 : 16 590 ATS (1 250 USD) net cost related to usable area; usable school area (classrooms) and usable gymnasium area: 1 824 m^2 school furniture: 2 367 000 ATS (178 000 USD) average for this building type (primary school): approximately minus 10%
0.7 Design costs	architect: 2 782 000 ATS (209 000 USD) structural engineer: 435 000 ATS (33 000 USD) technical facility engineer (heat, ventilation, sanitation): 281 000 ATS (21 000 USD)
0.8 Support from research funds	No

1. Design team

1.1 Architect	Arch. Mag. Ing. Helmut Deubner Hochwaldstraße 37 A-2230 Gänserndorf Süd Tel. + 43-2282-70289 project manager: Arch. Dipl.-Ing. Heinrich Schuller building surveyor: Arch. Johannes Breitling
1.2 Engineers, Structural	Dipl.-Ing. Franz Tatzber Steinbruchstraße 11a A-2452 Mannersdorf/Leithagebirge Tel. +43-2168-2114
1.3 Engineers, HVAC	Ing. Peter Trenkler Trumauer Str. 3 A-2482 Münchendorf, Tel. +43-2259-2312
1.4 Engineers, Energy / Comfort	Dipl.-Ing. Roland Phillip (thermal insulation / sound insulation / acoustics) Schloßgasse 14 A-3423 St. Andrä / Wördern, Tel. +43-2242-38751

1.5 Engineers, Electrical	Ing. Manfred Zivna Hungereckstr. 60/8 A-1230 Wien Tel. +43-1-6676060
1.6 Main Contractor	Contractors were contracted separately according to function and building component.
1.7 Contract form / Project organisation (see also 8.1-8.4)	The architect was responsible for the architectural concept and for the co-ordination of the design process and building process; surveyor *Is this the normal contract form in the country, if not describe the difference:* Normal contract form in the country.
1.8 Clients needs / wishes	Rather vague, specified as low operating cost, room programme (how many classrooms, secondary rooms, offices, gym, etc.) and as the wish to construct a building as ecological as possible (no targets set for instance concerning energy consumption); budget only 10% more than usual. *Describe the most important:* 1. functionality (specification very vague, wishes only concerning room programme and gym) 2. ecology and energy efficiency (no more detailed specification) 3. budget only 10% more than usual. Clients' wishes differed from users' (i.e. teachers) needs; the priorities of the teachers were as follows: 1. large classrooms, necessary in order to realise modern educational methods 2. easy control of children during the breaks (teachers opposed long corridors) 3. more space in the classrooms in order to stow away things. Teachers did not agree to free space classrooms because of difficult control and dirt problems. The client prioritised one central checkroom because of lower cost. Users prioritised a checkroom for each classroom, which would make it possible to utilise them twofold, as regular checkrooms and for project lessons. Architect and users put it through against the wish of the client.
1.9 Motivation for use of solar, PV, daylight etc.	Low operating cost, visual instruction for the pupils.
1.10 Obstacles for use of solar, PV, daylight etc.	Cost; public servants lack ecological awareness (members of the advisory council, see also 8.1; members of the building authority).

1.11 Lessons learned in the design process	Co-operation between architect and engineers has to be very close from the beginning in order to achieve good results. However, a whole building approach implies also problems. Each of the planning experts involved aims at a different goal, a specific goal according to a specific function. For instance it is the target of the engineer concerned with energy planning to minimise energy consumption; however, this conflicts with an architectural conception based on a large share of windowpanes. A guideline is needed on how to deal with these conflicts at the very beginning of the design process. It is a crucial point that the building techniques can be operated easily: the user has to be able to handle the technologies applied. It is useful to have clearly defined targets to avoid discussions without any direction. It is necessary to be aware of differing interests of groups involved. Interests of client and users might not correspond, e.g. in case of a school. Therefore design guidelines have to consider different “settings”.
1.12 Problems during realisation	Enterprises and public servants involved in the project lack experience with ecological construction. *Relate it to milestones in the design, how were initial decisions changed:* Initial decisions were changed because of user requirements (teachers): final planning stage.

2. Location

2.1 City, Country	Münchendorf, located in the province of Lower Austria (near Vienna), Austria
2.2 Latitude	48 N
2.3 Longitude	16.30 E
2.4 Altitude	200 m
2.5 Climate	Type: moderate Heating degree days: 3 322 (base = 20/12 related to a year, many years’ average) 3 175 (base = 20/12 related to the period 1.10. - 30.4.; according to Austrian standard ÖNORM B 8135) Cooling degree days: - (base =) Number of sunshine hours per year: 1 114 kWh/m^3 global radiation

3. Relation to Context

3.1 Degree of exposure	Free standing

3.2 Quality of environment	Fair conditions
4. Building parameters	
4.1 Number of floors	1
4.2 Size	Total usable area 1 824 m^2 Heated 1 824 m^2 Glazed spaces: recreational area 100 m^2 draft lobbies 30 m^2
4.3 Height	Floor to ceiling classrooms 3.20 – 4.0 m gymnasium 2.00 – 7.00 m others 2.80 m Gross m
4.4 Ceiling	Material: wooden-beamed ceilings; wooden covering in the classrooms; other rooms: partly wood and gypsum fibre boards; gymnasium: gypsum
4.5 Floor	Classrooms and gymnasium: solid wooden floor (beech) on a wooden sub-construction
4.6 Internal walls	Heavy
4.7 Construction type	Wood and brick Supporting walls: hollow bricks plastered; wooden-beamed ceilings and roofs.
4.8 Modulation	Cellular spaces: 8 classrooms Open planned spaces: Great hall: rather large, utilised twofold for musical education and events; no central checkroom, but each classroom supplied with a checkroom, daylit and furnished with a table to be used twofold for lessons as well; recreation room: winter garden with glass pyramid in the centre.
4.9 Insulation	Walls: cork, 80 mm U-value: 0.35 W/m^{2}K Roof: cellulose, 200 mm U-value: 0.18 W/m^{2}K Window panes: thermal protection glass; U-value: 1.40 W/m^{2}K U-value glass: 1.1 W/m^{2}K
4.10 Windows	Light transmission: 76% Total energy transmission: 60%
4.11 Window fraction (wall)	North 15% South 30% East 25% West 30%
4.12 Occupancy	Number of persons, totally: 8 x 30 (8 classrooms) Number of persons, per office / classroom: 30 Typical running hours: 8 - 14
5. Mechanical / Electrical parameters	

5.1 Energy consumption - net total for heating and electricity	Low: Gas: 90 kWh/m^2 (1997) Electricity: 12 kWh/m^2 (1997) Typical for building type: -
5.2 Heating system	Type: Low-temperature radiant wall heating in all classrooms supplied by a gas fired condensing boiler. Ceiling radiant heating in the gym: gas fired pipes with a high share of radiant heat. Because of the fast heat emission the temperature in the gym can be lowered during the non used times.
5.3 Ventilation	Natural, with the use of glazed spaces. Except the checkrooms and sanitary rooms of the gym according to building regulations; for ventilation of checkrooms and sanitary rooms waste air of the gym is used in order to reduce energy consumption. Mechanical without heat recovery in the checkrooms and sanitary rooms of the gym.
5.4 Installed Office Equipment	Few
5.5 Control	Individual: Each classroom is controlled individually according to the specific needs (depending on the kind of lesson).
5.6 Type of solar shading	external blinds, blinds of southern windows are operated individually controlled by the users fixed: protecting roofs

6. Technologies / Energy saving features

6.1 Use of passive solar	Yes: Classrooms and corridors: share of southern windowpanes is high Recreation room: winter garden.
6.2 Use of active solar	Yes: 16 m^2 solar collector on the southern wall of the gym to supply the showers with warm water
6.3 Use of daylight	Yes: Optimal distribution of daylight through additional daylight from above (roof windows), non-dazzling, daylight in all classrooms, offices and common rooms.
6.4 Use of photovoltaic panels	No
6.5 Use of rainwater	Yes: Water coming down the gutter is seeped away on the site; because of the high groundwater level water for the toilet flush and irrigation comes from a well; water saving fittings and flow controllers are used.

6.6 Sorting of waste	Yes: Separate waste collection (aluminium, metal, glass, organic waste, paper, toxic waste, others)
6.7 Use of environmental friendly materials	Yes: It was an important overall aim to avoid the sick building syndrome and to use ecologically beneficial materials only. External walls: bricks, cork insulation. Ceilings and roofs: wooden, cellulose insulation, no steam barriers, clay-tiled roof. Floors: in the classrooms solid wooden floors with cellulose insulation, surface treatment with vegetable oil and wax; tile pavement and cellulose insulation in secondary rooms and corridors. Wooden surfaces: treated with natural resin, wax. No PVC elements: high-grade steel fittings instead of PVC, wooden sign posting and directory. Wall painting: with natural paint.
6.8 Use of heat pumps	No
6.9 Use of BMS	No
6.10 Use of glazed spaces	Yes: Winter garden as draft lobbies; glass pyramid as recreational area which were planned to be equipped with plants, rocks and water. Teachers opposed it because of the requirement of a great deal of care. For this reason the recreation room remained empty and is used for events only. Children spend their breaks in the classrooms.
6.11 Use of energy efficient lighting	Yes: Daylight depending regulation of lighting; electric ballasts, Spiegelrasterleuchten.
6.12 Use of efficient heating technologies	Yes: Low-temperature radiant wall heating in all classrooms supplied by a gas fired condensing boiler. Ceiling radiant heating in the gym: gas fired pipes with a high share of radiant heat. Because of the fast heat emission the temperature in the gym can be lowered during the non used times.

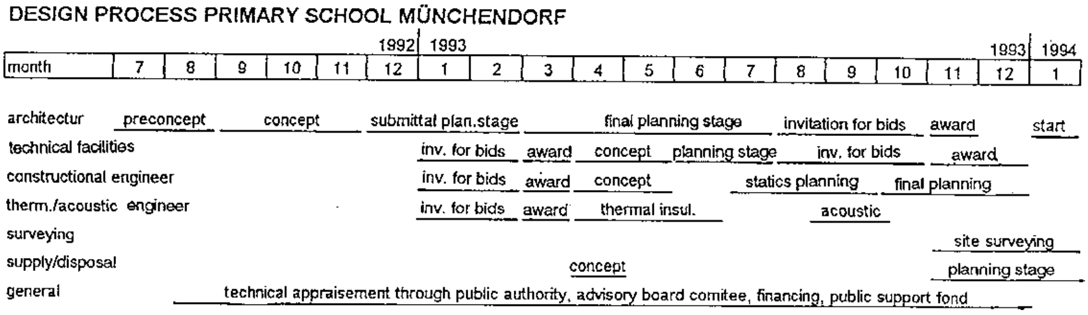
7. Real building performance

7.1 Description of building use *(Is it used as intended)*	Used as planned apart from the following changes: the recreation room was planned to be used both as recreational area and for events and actually is used for events only; one classroom was converted into a day nursery room with a kitchen in the last moment.
7.2 Performance problems, and reasons	*Compare objectives and actual performance:* Occupants had to learn the handling of oil/wax - treated wooden floors and the operation of the heating control system.
7.3 Occupancy reactions	Occupants are very satisfied, children highly motivated.

7.4 Side effects (PR, Green label etc.)	The government of the Province of Lower Austria asked for the tender documents; they were interested in the ecological performance of the building to be used as a standard for the construction of schools, however they did not follow this intention.

8. Design process

8.1 Chart describing the design process



8.2 Summary description of the story / the design process

8.2.1 Background: Why was the building built? Context, reasons for location

The local authorities of Münchendorf contacted the architect; the client's wish was an ecological primary school in general that should especially meet high standards concerning indoor climate and use of non-polluting materials. Another important criterion was low operating cost. No specific targets were set such as a certain amount of energy consumption per square metre The performance of the building to be constructed should be generally better than the performance of a building constructed according to building regulations.

The local authorities of Münchendorf commissioned the project. As usual the Province of Lower Austria subsidised the construction of the building to a certain extent: concerning school buildings the local authorities mainly pay for the operating cost of the primary schools located in their district, and so does Münchendorf. That is why low operating cost was an important decision criterion for the choice of technologies and materials.

There were two reasons for the location of the primary school:

- building site owned by the municipality
- sports ground next to the building site

The municipality also owned a building site in the centre of Münchendorf. Because of lack of space they decided to choose the building site outside and benefit from the sports ground already existing.

The decision upon the building site had been made already when the architect entered the project.

8.2.2 Planning process, alternative designs

Design phase started with two very different concepts drafted by the architect, one of them to be chosen by the client. The variant rejected was designed as a long glass house with the classrooms inserted as cubes. If this variant had been chosen it would have been necessary to do energy simulations. The design chosen was considered to be a conventional one with well known „behaviour" with respect to energy issues. Heating energy demand was calculated according to Austrian Standard ÖNORM 8110. It was not necessary to do simulations on the chosen variant because of sufficient experience with the construction method applied.

The design team consisting of the architect and the planning experts elaborated on the chosen concept. The architectural concept was elaborated and modified according to the results of the discussions with the planning experts. Crucial decisions were discussed with the advisory council. As a member of the advisory council the client was involved in all steps of the design process. In addition meetings took place to discuss pedagogical aspects with the teachers. Conflicts raised, wishes/needs/preferences differed and went beyond the budget.

With respect to children's needs it was clear from the beginning that the building would not be a compact one but would offer outdoor spaces and green spaces which were considered to be more important than a better energy performance resulting from an improved surface/volume ratio.

To achieve the result required the experts involved in the project did their planning parallel to each other; exact planning targets and constant meetings were necessary to adjust and co-ordinate partial results.

It was the architect's task to evaluate the contribution of each planning expert concerning its accordance with the primary project goals.

The client, the advisory council and the planning experts could hardly cope with this comprehensive task: to find the optimal solution between pedagogical, ecological, energetic and financial requirements.

Especially the client's and advisory council's lack of knowledge and lack of experience with ecological construction were difficult to handle.

8.2.3 Decision process

Choice of technologies and materials was done based on experience. Criteria for decision-making were ecological performance and cost. Choice of wall insulation material for instance went this way: materials under consideration were materials usually used (polystyrene) as well as environmentally beneficial materials such as cork. Polystyrene was excluded because of environmental reasons, cork was chosen because of cost efficiency reasons.

In case of competing options the process followed the guideline:

- which criterion is (are) the most important one
- which criteria are met by one option only
- which criteria are met by more than one option

Decisions were done by comparing operational cost with investment cost. Investment cost are subsidised, therefore the local authority (client) is affected by the operational cost mainly.

Trade offs:

- Control system for space heating: energy savings versus comfort (see 8.3)
- Energy carrier for space heating: reduction of CO2 emissions versus cost and infrastructural preconditions (see 8.3). Infrastructural preconditions are very important. Cost efficiency is a strong reason to decide in favour of a technology and often depends on the regional tariff structure. For instance, with respect to feeding into the grid this is a barrier to PV in Austria.
- Thermal insulation: energy savings versus cost. Heating energy demand calculations according to Austrian Standard ÖNORM B 8110 were done in two versions, 1) meeting the demands given by legislation and 2) using the insulation data suggested by the architect and the energy engineer. The results convinced the client to agree to higher investment cost and benefit from low operational cost.
- Provision of green / free spaces: energy savings versus well being. With respect to children's needs it was clear from the beginning that the building would not be a compact

one but would offer outdoor spaces and green spaces which were considered to be more important than a better energy performance resulting from an improved surface/volume ratio.

- Use of thermal solar for warm water despite higher cost: because of image reasons: „an ecological building has to use thermal solar“.
- Use of natural materials despite of high cost: because of image reasons: „an ecological school has to use furniture made from wood“.

All other measures were implemented because cost efficiency could be proved. Costly measures could be realised because money was saved in other places, such as avoiding mechanical ventilation by means of careful architectural planning.

8.2.4 Project organisation

The client commissioned the architect to work out the architectural concept and to co-ordinate the planning experts in order to achieve the result required, an ecological primary school. So the architect selected the members of the planning team on the following criteria: experience on solar and ecological technologies and construction (call for tender). The local authority of Münchendorf accepted the planning experts proposed by the architect and contracted each of them individually.

An advisory council accompanied the planning process. The council consisted of representatives of the local authorities of Münchendorf, the province of Lower Austria (engineers and experts on finance), representatives of the institution concerned with financing (a co-operative, that also does the planning and constructing of buildings in other cases), and the architect.

During the planning process the advisory council met once to twice a month at the call of the architect. The meetings took place at crucial phases in the planning process, when important decisions had to be made.

The participants in the project were different interest groups with differing targets:

Client: operational cost, image

Teachers (user): room temperatures have to be adjustable in a very flexible way, no trouble with dirt, easy supervision of children, rooms allowing the application of modern pedagogical methods

The client took part in the design process (the advisory council); the architect additionally involved the teachers in a later stage. It would have been useful to integrate the teachers in the team in order to optimise the planning result. The glazed space was planned to serve as a green space with rocks, plants and water for relaxing and as a place for events. Because of high effort to care for plants and water and concerns of teachers with respect to trouble with dirt and supervision of children there are no plants and water and the place is used for events only.

If the teachers' targets had been integrated at the beginning of the design process the building would look different today. However, due to the fee structure most of the time pre design is done by the architect himself. Fee structure and tendering are the most important barriers to an integrative design approach.

8.3 Description of and motivation for phenomena that have been investigated (technical, architectural, materials etc.)

8.3.1 The wishes of the client were specified as

- the construction of an ecological building and
- cost efficiency, especially low operating cost.

There are several options (technologies, materials) to provide the services (for instance warm space) required by the client. According to the wishes from the client, in this case only technologies and materials meeting ecological requirements were considered (non-polluting, utilisation of renewable resources, energy efficiency, low consumption of fossil fuels, reduction of drinking water consumption).

In the very beginning it was decided that the building would not be a compact one because the creation of protected and useably free spaces was highly prioritised.

The decision for one of several options taken into consideration was based on discussions with the advisory council. The results of cost efficiency analyses stressing operational cost prepared by the architect were important criteria for the choice of technologies and materials.

Aiming at high ecological standard and low cost the architect used sophisticated architectural design instead of expensive technologies (for instance ventilation).

Another reason for this concept was the experience that design should ensure the simplest possible operation of a building.

The user accepts a technology if it is understandable. That is a crucial point also concerning energy efficient technologies: highly sophisticated technologies do not save energy if the user cannot handle them.

8.3.2 Lighting

Daylight and efficient artificial lighting with daylight depending control system: cost efficiency could be proved.

8.3.3 Water supply

Decision for the use of ground water use because of cost efficiency.

Warm water (showers): Solar collector despite of high cost.

Space heating: Low-temperature radiant wall heating; gas-fired condensing boiler because of existing gas supply system and low cost; the ecologically optimised alternative would have been biomass and solar heating.

In addition an emergency chimney was installed in the great hall.

8.3.4 Control system (space heating)

Control of space heating was designed to ensure the simplest possible operation. It is the experience of the architect that the user for the reason of lacking understanding does not accept sophisticated control systems. Individual operation is required, however, this often accounts for sub-optimal operating conditions.

In Münchendorf classrooms are controlled individually by the teacher to meet the needs for changing temperatures according to the kind of lesson. There was a computer based self-learning system under consideration as well. The operation, however, turned out to be too complicated.

8.3.5 Ventilation

There is no mechanical ventilation in the classrooms and the gym. Circulation of air is ensured as a result of careful architectural planning. Mechanical ventilation of the checkrooms and sanitary rooms in the gym according to building regulations: waste air of the gym is used in order to reduce energy consumption.

8.4 Resources used (rules of thumb, simulation programmes, workshops, experts, literature etc.)

1) The design process followed the guideline „TOP Teamorientiertes Planen. Schweizerischer Ingenieurs- und Architektenverein (sia), Bundesamt für Konjunkturfragen, Bern 1996".
2) Choice of technologies and materials was done based on experience (see 8.2 Decision process).
3) Heat demand calculations: engineers used software developed by themselves, EXCEL-Sheets adapted to their needs.

Pro Solar kooperative Planungswerkstatt now uses:

- WAEBED: simulation programme to determine daily heat losses and heat demand per room
- KENN 8110: programme to examine overheating in summer
- TELPHYS: U-values, sound insulation
- SHW: Dimensional analysis of solar collectors

8.4.1 At which stage of the design process were the resources used?

Resources were used during final planning stage mainly. The client started to show interest in the project after the building permit had been approved and interest in the project grew with project progress.

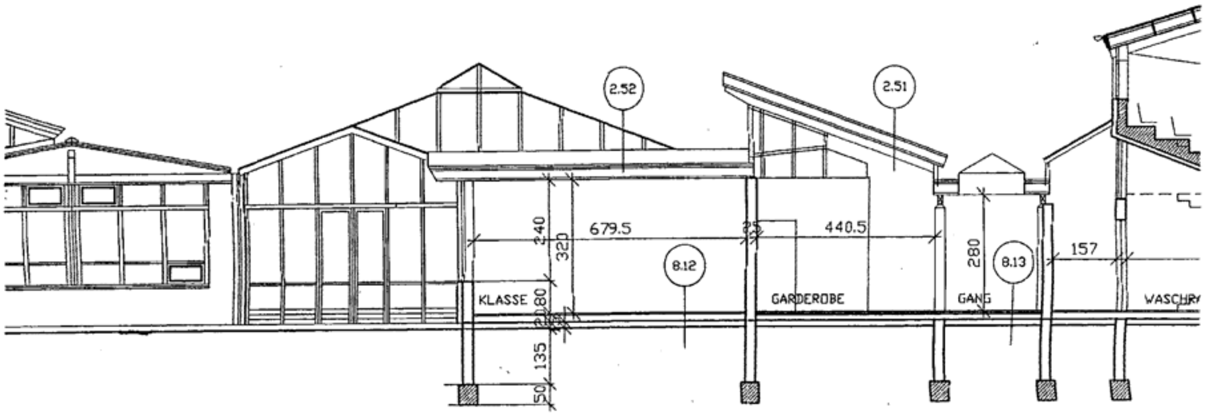
8.4.2 Were they used as a help to design the building ***or*** *used to see the consequences of the already designed building?*

Heat demand calculations were used to see the consequences of the already designed building.

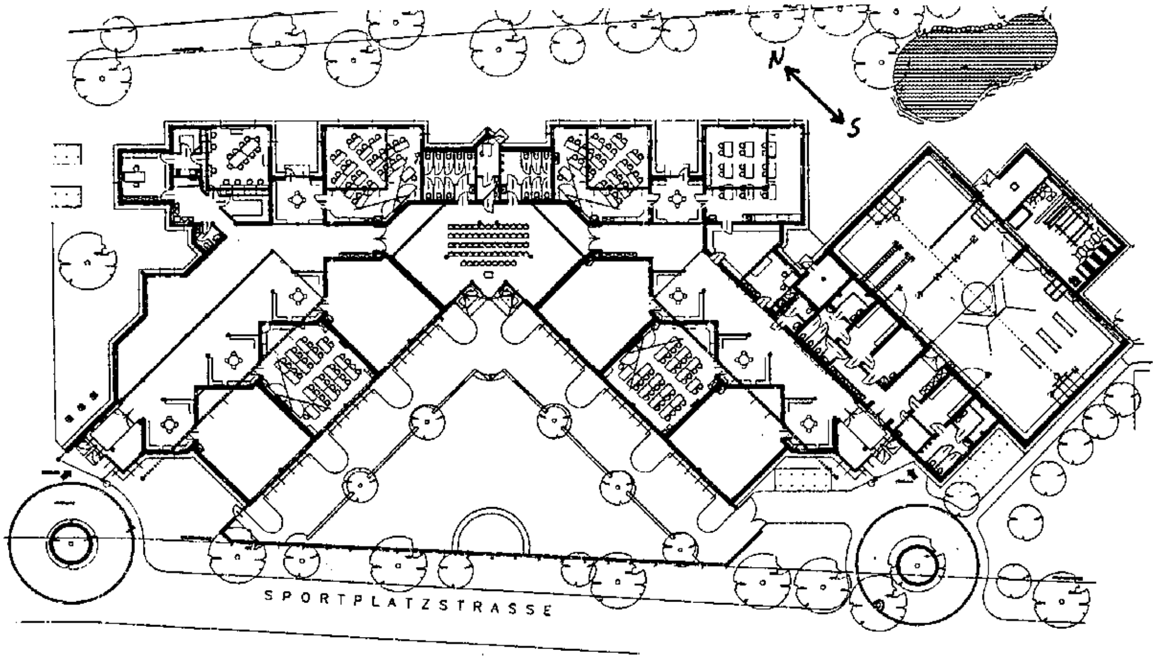
Heat demand was calculated twice according to Austrian standard: once with thermal insulation according to building regulation, once with the thermal insulation planned. The comparison of results served the justification of higher construction cost as operational cost was prioritised.

9. Drawings and photos

9.1 Typical cross-section



9.2 Typical floor-plan



9.3 Photos of the building

Case Story no. 2:

Sparkasse Bludenz, Austria

Further information:

Wibke Tritthart
Interuniversity Research Center for Technology, Work and Culture
Schlögelgasse 2
A-8010 Graz
Phone: +43 316 813 909 23
Fax: +43 316 810 274

0. Overall

0.1 Name of building	Sparkasse Bludenz, Head office
0.2 Type of building	Bank and automatic multi-storey car park ("Car-safe")
0.3 Owner / Operator	Sparkasse Bludenz
0.4 Construction	Autumn 1995 - Autumn 1997
0.5 Planning time	Winter 1994 - Spring 1996
0.6 Building costs	Total: 94 000 000 ATS (7 072 000 USD) (exclusive of 20% value added tax) per m^2 (gross): 23 500 ATS (1 770 USD) (including car-safe) average for this building type: This is approx. the average for this building type in West-Austria.
0.7 Design costs	17 000 000 ATS (1 279 000 USD) (exclusive of 20% value added tax)
0.8 Support from research funds	No

1. Design team

1.1 Architect	Arch. Dipl.Ing. Richard Nicolussi Untersteinstraße 23 A-6700 Bludenz Tel.: +43 / 5552 / 65030
1.2 Engineers, Structural	Dipl.Ing. H. Zierl, Dipl. Ing. CH. Gantner A-6700 Bludenz
1.3 Engineers, HVAC	BHM Ingenieure Langgasse 108 A-6830 Rankweil Tel.: +43 / 5522 / 461010
1.4 Engineers, Energy / Comfort	BHM Ingenieure Langgasse 108 A-6830 Rankweil Tel.: +43 / 5522 / 461010 *Building physics (acoustics etc.):* Karl Wille Auf der Ratsch 6820 Franstanz Tel.: +43 / 5522 / 51150

1.5 Engineers, Electrical	BHM Ingenieure Langgasse 108 A-6830 Rankweil Tel.: +43 / 5522 / 461010 *Daylighting:* Bartenbach LichtLabor GmbH Rinnerstraße 14 A-6071 Aldrans Tel.: +43 / 512 / 3338-0
1.6 Main Contractor	Contractors were contracted separately
1.7 Contract form / Project organisation (see also 8.1-8.4)	The members of the design team were contracted separately by the client. The architect proposed the engineers and was the co-ordinator of the team. *Is this the normal contract form in the country, if not describe the difference:* This is the normal contract form in Austria.
1.8 Clients needs / wishes	*Describe the most important:* The old part of the bank, a building dating from 1956, had to be refurbished and a new part designed taking into account the following criteria: transparency, low energy consumption, low construction costs, optimised working conditions, environmental protection. The client specified his needs concerning rooms, functional aspects and organisation of the future work in a 3-year discussion process. A competition was held to choose the design best suitable for the specified purpose.
1.9 Motivation for use of solar, PV, daylight etc.	Solar energy use fulfilled all relevant design criteria. But it was nevertheless a long way to obtain the approval of the client.
1.10 Obstacles for use of solar, PV, daylight etc.	Extra costs, technoid character/appearance
1.11 Lessons learned in the design process	Close co-operation between the design team and the client was absolutely necessary. Environmentally sound features with moderate costs and high workplace quality met with the highest degree of approval.
1.12 Problems during realisation	*Relate it to milestones in the design, how were initial decisions changed:* For the client it was very difficult to visualise the planned daylight components and their benefits for the working places. Therefore a ”model-room” was built. Because of the daylighting the surfaces and materials had to be chosen before the use of the room was fixed.

2. Location

2.1 City, Country	Bludenz, province of Vorarlberg, western part of Austria
2.2 Latitude	47 N
2.3 Longitude	15.2 E
2.4 Altitude	600 m
2.5 Climate	Type: Alpine – moderate Heating degree days: 3 919 Kd/a (base = 20/12, 20°C is the norm room temperature, 12°C is the outside temperature characterising the beginning and the end of the heating period) Cooling degree days: not available (base =) Number of sunshine hours per year: not available (Global horizontal radiation is 1 081 kWh/m^{2}a)

3. Relation to Context

3.1 Degree of exposure	Obstructions: It is in an urban area
3.2 Quality of environment	Pollution and noise: Located on a downtown main road

4. Building parameters

4.1 Number of floors	5 (including basement and a partly extended attic storey)	
4.2 Size	Total Heated Glazed spaces	4 000 m^2 (gross) 3 000 m^2 (net) 250 m^2 (net)
4.3 Height	Floor to ceiling Gross	2.5 - 3 m 18 m
4.4 Ceiling	False ceiling of aluminium / gypsum fibreboard	
4.5 Floor	Terrazzo (stone), carpet	
4.6 Internal walls	Light	
4.7 Construction type	Concrete	
4.8 Modulation	Partly Cellular spaces and open planned spaces	
4.9 Insulation	Walls: 10 mm, U-value: 0.3 W/m^{2}K Roof: 16 mm, U-value: 0.25 W/m^{2}K Window panes: U-value: 1.1 W/m^{2}K Glazing of the attached sunspace: single layer	

4.10 Windows	Light transmission: 80% Total energy transmission: 60%
4.11 Window fraction (wall)	North 14% South 16% East 0% West 70%
4.12 Occupancy	Number of persons in total: 65 Number of persons per office: 2 – 8 Typical office hours: 8 a.m. - 5 p.m.

5. Mechanical / Electrical parameters

5.1 Energy consumption - total for heating and electricity (net, secondary energy)	Low: 30 - 35 kWh/m^2 – including cooling, without lighting and plug loads Typical of building type: 70 –100 kWh/m^2 (new)
5.2 Heating system	Type: gas-fired condensing boiler, low-temperature distribution system: Each office room has 2-3 very small radiators with a temperature of 55 degrees Celsius
5.3 Ventilation	Mechanical with heat recovery, but windows can be opened in a glazed sunspace
5.4 Installed Office Equipment	Average: 1 personal computer per work place
5.5 Control	Individual and Computer-based
5.6 Type of solar shading	Prismatic plate, situated in the attached sunspace, computer controlled, vertically rotating

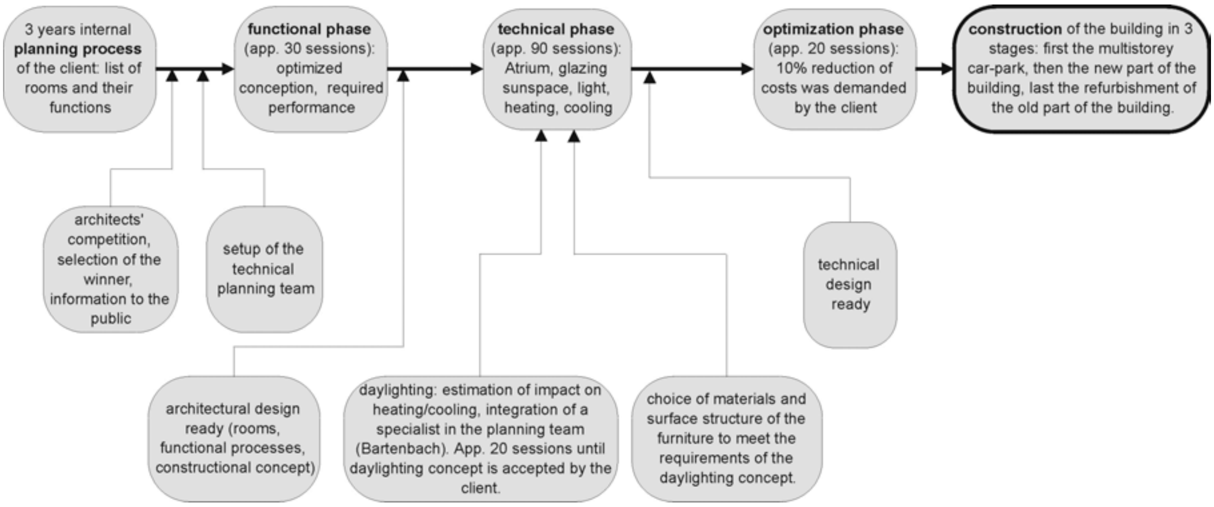
6. Technologies / Energy saving features

6.1 Use of passive solar	Yes: The upper parts of both central atria are used as heat collectors, where the vitiated air is sucked away. The south and west facades of the buildings are surrounded by an attached glazed sunspace
6.2 Use of active solar	No
6.3 Use of daylight	Yes: Prismatic plate as shading for direct light, mirrored window shutters reducing glare and directing diffuse light on to the reflective ceiling
6.4 Use of photovoltaic panels	No
6.5 Use of rainwater	No
6.6 Sorting of waste	Yes: Collection of metals, paper and toxic waste
6.7 Use of environmental friendly materials	Yes: Wood furniture with solvent-free varnish, cork as internal insulation material, no PVC

6.8 Use of heat pumps	No
6.9 Use of BMS	Yes: Installation bus system controlling ventilation, heating, lighting and safety. Artificial lights are switched off automatically after a time period, which depends on the external illumination (external sensor). 4 scenarios are defined for heating and ventilation (ordinary working day, night time, weekend,...)
6.10 Use of glazed spaces	Yes: 2 atria and an attached glazed sunspace. The function is described in 6.1
6.11 Use of energy efficient lighting	Yes: Indirect lighting (quartz lamps directed at a special part of the reflective ceiling) is used mainly because of the low ceiling height in the rooms. The energy consumption is only 7 W/m^2.
7. Real building performance	
7.1 Description of building use *(is it used as intended)*	used as intended
7.2 Performance problems, and reasons	*Compare objectives and actual performance:* In the beginning the staff could not believe that closing the window shutters improves the lighting of the working place. Cleaning of the various components of the daylighting system might be a problem.
7.3 Occupancy reactions	The employees and the customers are very satisfied with the project. "Guided tours" have been organised for the employees and the public.
7.4 Side effects (PR, Green label etc.)	The building serves as an example of extensive and cost-effective daylighting (payback time 8 – 12 years) for the designers and the client. Until now 60 groups of visitors have shown interest in guided tours.

8. Design process

8.1 Chart describing the design process



8.2 Summary description of the story / the design process

8.2.1 Background: Why was the building built? Context, reasons for location

An extension had to be added to the head office of the Sparkasse Bludenz (a regional bank), a building dating from 1958. In addition, the building did not meet the modern comfort requirements of employees and customers. The room height of the first and the second floor (office rooms) was only 2.60 m and 2.40 m, respectively. The floor plan was confusing and the atmosphere rather dim. The bank is situated in the centre of a small town in the Alps and was one of the few urban buildings there, remarkable also because of its marble facade, which had to be preserved.

8.2.2 Planning process, alternative designs

Several architects presented different concepts at the competition, some even proposed to pull down the old part and construct an entirely new building. Low energy consumption of the building had not been formulated as a requirement for the competition.

The winning architect kept the lines of the old building to follow them in the new part. In particular the floor levels remained unchanged. This implied that no suspended luminaries could be used for lighting purposes because of low room heights. For the same reason the ventilation system could not be installed in the ceiling.

The architect suggested a glass facade, which should cover the old marble facade and the facade of the new part and lead to a uniform appearance of the whole building. Furthermore, this was a way to improve the U-value of the building shell and to reduce traffic noise in the offices. It turned out that the sunspace thus created made it possible not only to use passive solar gains, but also to accommodate the daylighting system in a sheltered place.

Concerning building costs, the client's guidelines were based on bank buildings erected in the province of Vorarlberg in the past few years. Once the idea of using daylighting strategies was introduced by the planning team, the client had to be convinced that this was a cost-effective solution. This was the beginning of a very intense communication among the architect, the planners and the client. The interdependencies of the various design elements became clear: No glazed sunspace meant no daylighting system, no daylighting system meant that the marble facade could not be preserved entirely, bigger cooling machines were necessary, which would in its turn increase energy consumption and the price of the machines. A daylighting engineer was integrated into the planning team, and topics of future energy consumption and different heating and cooling concepts were discussed in much more detail than is usually the case during the design process. Design with or without daylighting system in the attached glass facade had consequences on the dimensioning (and thereby the investment and operating costs) of the cooling system and the operating hours of the artificial lighting. In the optimisation phase some elements of the daylighting system were reduced in area and in complexity (manually operated instead of automatically).

Nevertheless, the client was hard to convince to spend money on a daylighting system. The calculations showed that the payback time was 8 to12 years. Even more important was the improved quality of each working place. The decision in favour of the daylighting system was taken after a visit to the Bartenbach LichtLabor, where a model of an office room was built and tested.

8.2.3 Decision process

The bank set up a committee comprising two members of the management, a representative of the employees and two account managers. All solutions concerning specific design details were presented to this committee, whose questions were very critical. The advantage of this intense communication process - about 140 sessions were held - was that the client in the end really identified with the project. The client also informed the politicians and the public from time to time, which is very important for promoting an innovative building project in a small town. The enormous public interest was revealed at the opening of the new building, which attracted about 10 000 visitors (in a town of 12 000 inhabitants).

Several trade offs were already taken into account within the architectural concept, e.g. the wish to preserve the old marble facade, but improve the poor U-value. The solution in this case was the attached glass facade.

The unshaded roofs of the atria on the one hand give more light in the interior rooms, but on the other hand would overheat the corridors in the upper storeys (first and second floor) in summer. So a transparent wall (glass) separated the air volumes of the atria and of the other parts of the upper storeys. The atria are used as (warmer) buffer rooms.

Costs versus benefits of the daylighting system: The benefits are better light at the working places (enough daylight without glare problems during 85% of the office hours of the bank), more effective sun shading (the prismatic system reduces the cooling load by 50%) and the harmony with the aesthetic concept. The benefits had to be quantified for the client. The decision in favour of the concept was taken because of the enthusiasm and the persistence of the architect, who convinced the client and the design team. During the optimisation phase of the design process the daylighting system was reduced to the extern necessary to meet the basic requirements.

The indoor materials (especially the surfaces) had to meet conflicting demands (concerning acoustics, lighting and preferences of the client). Therefor the choice fell on reflecting ceilings and walls (in the counter hall) with holes punched in them. Dark colours were excluded.

Costs and benefits of the artificial lighting system: a central sensor on the roof controls the artificial lighting. It comprises four computerised scenarios with continuously dimmed areas (offices) and timer-controlled areas (corridors). During the optimisation phase cost effectiveness had to be proven by an analysis of the operation hours.

8.2.4 Project organisation

The client started the project with a three-year internal planning process. The team consisted of representatives of the bank. An enlarged team (board of directors of the bank, public representatives) took major decisions. The result was a list of rooms and their functions, the basis for the architectural competition, time schedule and financial frame.

The second stage was the design process, consisting of three sub-processes ("functional phase", "technical phase" and "optimisation phase"). The team members differed in the different phases.

"Functional phase": architect, structural engineer, building physics engineer (acoustics), electrical and HVAC engineers, representatives of the client (5 persons).

"Technical phase": The composition varied depending on the subject of the meeting. The architect, HVAC engineers, daylighting engineer, representatives of the client (5 persons) were present all the time, while the electrical engineers, structural engineer, building physics engineer participated in some meetings only.

"Optimisation phase": architect, electrical and HVAC engineers, daylighting engineer, representatives of the client (5 persons).

The design process resulted in plans to be submitted to the local authorities (by the architect), detailed drawings for the constructing firms (by the architect and engineers), information on the masses of the construction materials and on the costs (by the architect).

The third stage was the construction process (first the car park, then the new part, finally the refurbishment of the existing part). The team consisted of the architect and the construction process manager (Arch. Dipl.Ing. Anton Kuthan, Bludenz). The building was constructed within the estimated costs.

The roles of the different participants were:

Architect: design, leader of the design team, proposal of innovative ideas, financial aspects during the design process, public relations.

Structural engineer: structural concept and details.

HVAC-engineers: design of the HVAC systems, technical in keeping to deal with the design ideas of the architect, calculation of the effects of the daylighting system on the cooling machine, calculation of the effects of the sunspaces (atria, attached glass facade),

Electrical engineers: electrical equipment of the building, artificial lighting system

Building physics engineer: acoustics.

Daylighting engineer: concepts for daylighting (3 different systems were proposed), construction of a "model room", excursions to some international projects with the design team.

Client: PR-work, request of cost benefits calculations, demanding "optimisation phase" (cost reduction).

All members: discussion of trade offs and alternatives, decisions to reduce costs in the optimisation phase.

8.3 Description of and motivation for phenomena that have been investigated (technical, architectural, materials etc.)

8.3.1 Sunspace (attached glass facade)

A glass facade covers the facade of the first and the second floor of the building. The space in between provides a shelter for the daylighting system against dirt and bad weather conditions. The glass facade is connected to the wall of the ground floor by means of a grating, which acts as a sound-absorbing device and is equipped with a dust filter. A valve that is controlled by humidity and temperature provides the upper connection to the roof. Hence, natural ventilation of the office rooms in winter and summer is possible without energy losses.

8.3.2 *Daylighting*

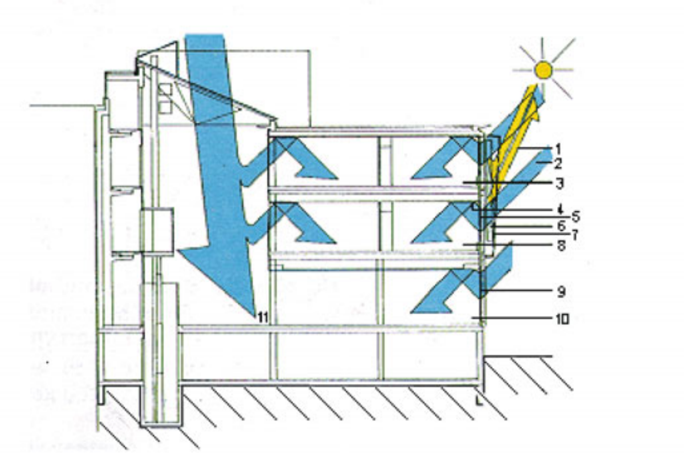
The daylighting concept uses several different components to obtain its central functions of solar shading and glare reduction. At the facade of the first and second floor solar shading is effected by vertically rotating prismatic plates. They are always adjusted normally to the direction of the sunlight. The direct sunlight is reflected and is not converted into heat. 80-90% of the diffuse sunlight is allowed to pass to illuminate the room. When the sky is overcast, the plates are adjusted normally to the facade to allow for maximum view.

To cope with the persisting differences in light levels (sunlit window - dark wall), glare reduction is necessary. Traditionally it is provided by blinds, whose disadvantage lies in the reduced luminance of the room. The most intelligent solution is the use of (specially designed) reflective blinds that direct the diffuse light to a reflective ceiling, from which it is again reflected down to the working place.

The Sparkasse Bludenz was equipped with mirrored window shutters. To reduce costs they only cover the central part of the window, which allows for optimisation of reflection conditions and provides a glimpse of the world outside. The user operates them, and can decide to get better light on his desk by accepting less view. Especially in the beginning employees tended to open the shutters, whereas now more and more shutters remain closed.

The atrium provides another source of (diffuse) daylight. Illumination of the rooms, in this part of the building there are corridors, reception and meeting rooms, can again be improved by simple reflective blinds and a conventional reflective ceiling.

The daylighting concept can be seen in the figure below.



1 direct sunlight
2 diffuse sunlight
3 second floor, office rooms
4 reflecting ceiling
5 glare reduction component
6 sunshading component
7 attached glass facade
8 first floor, office rooms
9 glare reduction component
10 ground floor, counter hall
11 atrium, counter hall

8.3.3 *Artificial Lighting*

The artificial light concept is adapted to the daylight scenario. Pole luminaries cast light of HQI quartz lamps to a specially structured area of the reflective ceiling. The overall background illumination is provided by indirect recessed luminaries equipped with the same type of lamps. Thus, an evenly distributed luminance and no glare, regardless of position in the room and direction of view, could be realised.

8.3.4 *Atrium*

Two atria are designed as thermal buffers. Their common ground floor forms the central hall of the bank. A glass wall separates the upper parts of the atria from the offices and corridors situated on the first and second floors, which makes it possible to suck off the warm air at the top and feed it into a heat recovery unit for ventilation purposes.

The atria also function as sources of daylight for the interior rooms. The light of upward-directed pole luminaries is reflected down via reflective "clouds" (pendent metal disks).

8.3.5 Attic storey

The meeting and training room in the attic provides a splendid panorama view of the town of Bludenz and the surrounding mountains. The south, west and north sides of the room are enclosed by silver-coated windowpanes: The energy transmittance (g-value) is about 20% to avoid glare and overheating in summer. Illumination comes from a skylight situated in the centre above the main conference table, thus lighting the work area and the participants in the meetings. This ensures a ”democratic distribution of luminance”: Nobody has to look at a bright window with people in front of it being in the dark.

8.3.6 Heating/ventilation/cooling concept

The distribution conduits of the low-velocity ventilation system pass vertically through the building, which does not lead to a reduction in room height (no conduits in the ceiling or floor). In the central hall the thermally induced airflow up the atria is slow and does not cause any discomfort.

Other parts of the HVAC have already been described: heat recovery for ventilation air, gas boiler for an additional room heating by a low-temperature water distribution system. Natural ventilation with tempered air via the sunspace.

8.4 Resources used (rules of thumb, simulation programmes, workshops, experts, literature etc.)

The daylighting system was designed with software by Bartenbach. The heating and cooling energy need was calculated using the standard formulas specified by ÖNORM (Austrian Standards Institute).

8.4.1 At which stage of the design process were the resources used?

Computer graphics were used to visualise the rooms in three dimensions, the indoor surface materials, etc. during the technical phase of the design process. A model room was built to show the effects of the daylighting system.

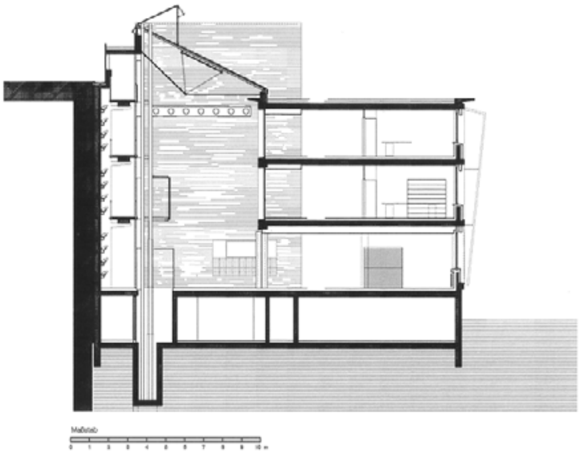
Calculations of the energy consumption of the building were updated several times mainly during the technical phase.

8.4.2 Were they used as a help to design the building ***or*** *used to see the consequences of the already designed building?*

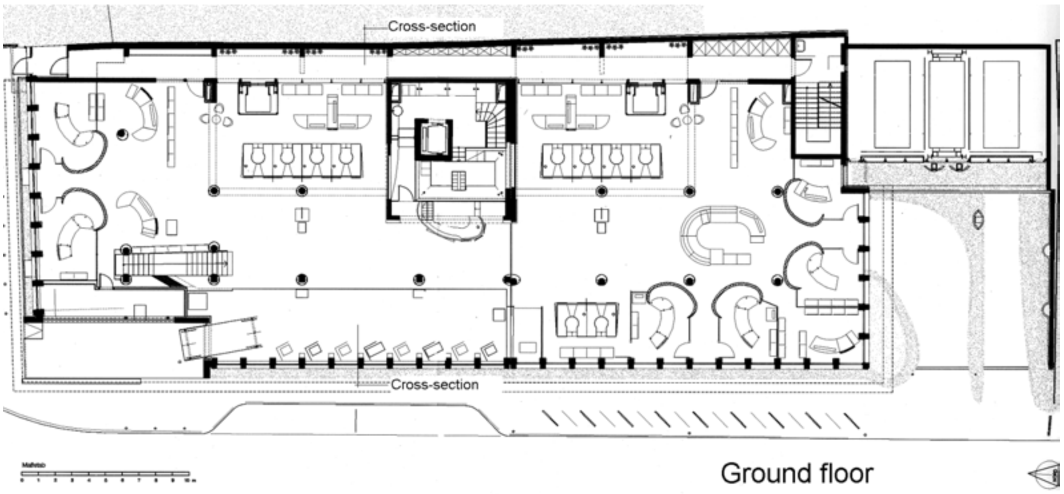
The energy consumption calculations were used to show the consequences, especially of the daylighting system and of the unshaded atria.

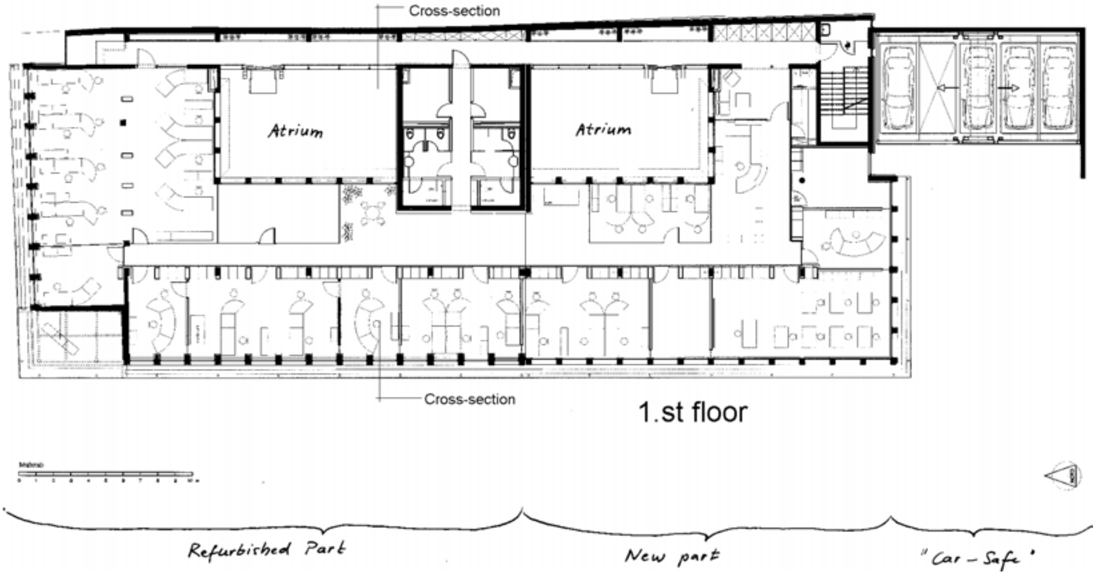
9. Drawings and photos

9.1 Typical cross-section



9.2 Typical floor-plan





9.3 Photos of the building

West facade

Counter hall and atrium

Participants in Task 23

Austria:
Susanne Geissler
Österreichisches Ökologie-Institut
Seidengasse 13
A-1070 Wien
E-mail:
oekoinstitut.econ@ecology.at

Wibke Tritthart
Interuniversity Research Center for Technology, Work, and Culture
Schlögelgasse 2
A-8010 Graz
E-mail: tritthart@ifz.big.ac.at

Canada:
Nils Larsson
Canmet Energy Technology Centre
13/F, 580 Booth St.
Ottawa, KIA 0E4 Canada
E-mail: larsson@greenbuilding.ca

Denmark:
Torben Esbensen
Esbensen Consulting Engs.
Møllegade 54
DK-6400 Sønderborg
E-mail: torben.esb@esbensen.dk

Christina Henriksen
Esbensen Consulting Engs.
Vesterbrogade 124 B
DK-1620 København V
E-mail: c.henriksen@esbensen.dk

Søren Aggerholm
SBI, Box 119
DK-2970 Hørsholm
E-mail: soa@sbi.dk

Finland:
Jyri Nieminen
VTT Building Technology
P.O. Box 1804
FIN-02044 VTT
E-mail: jyri.nieminen@vtt.fi

Pekka Huovila
VTT Building Technology
P.O. Box 1801
FIN-02044 VTT
E-mail: pekka.huovila@vtt.fi

Germany:
Günter Löhnert
SOL.ID.AR
Forststrasse 30
D-12163 Berlin
E-mail: solidar@t-online.de

Matthias Schuler
TRANSSOLAR
Nobelstrasse 15
D-70569 Stuttgart
E-mail: schuler@transsolar.com

Japan:
Mitsuhiro Udagawa
Dept. of Architecture
Kogakuin University
1-24-2 Nishi-Shinjuku, Shinjuku-ku
Tokyo 163-8677 Japan
E-mail:
udagawa@cc.kogakuin.ac.jp

Netherlands:
Bart Poel
Damen Consultants
Box 694
NL-6800 AR Arnhem
E-mail: ap@damenconsultants.nl

Gerelle van Cruchten
Damen Consultants
Box 694
NL-6800 AR Arnhem
E-mail: gc@damenconsultants.nl

Zdenek Zavrel
Atelier Z, St.Jobsweg 30
Postbus 64093
NL-3002 JB Rotterdam
E-mail: atelierz@xs4all.nl

Norway:
Anne Grete Hestnes
Dept. of Building Technology
NTNU-Gløshaugen
N-7491 Trondheim
E-mail:
annegrete.hestnes@ark.ntnu.no

Inger Andresen
SINTEF Architecture &
Building Technology
N-7465 Trondheim
E-mail:
inger.andresen@civil.sintef.no

Per Kr. Monsen
Gasa Architects A/S
N. Slottsgt. 11
N-0157 Oslo
E-mail: per.monsen@gasa.no

Spain:
Luis Alvarez-Ude
A.U.I.A., c/Papa Negro 41B
Parque Conde de Orgaz
E-28043 Madrid
E-mail: auia@ran.es

Manuel Macias
A.U.I.A., c/Papa Negro 41B
Parque Conde de Orgaz
E-28043 Madrid
E-mail: auia@ran.es

Sweden:
Maria Wall
Dept. of Building Science
Lund University, P.O.Box 118
S-22100 Lund
E-mail: maria.wall@bkl.lth.se

Switzerland:
Pierre Jaboyedoff
SORANE SA
Route de Châtelard 52
CH-1018 Lausanne
E-mail: sorane@worldcom.ch

Werner Sutter
H.Bosshard & W.Sutter Arch.
Kirchenstrasse 13
CH-6300 Zug
E-mail:
architects.b.and.s@bluewin.ch

USA:
J. Douglas Balcomb
NREL, 1617 Cole Blvd.
Golden, CO 80401 USA
E-mail: doug_balcomb@nrel.gov

Facts
Primary School, Austria
Architect: Helmut Deubner
Photo: Heinrich Schuller

Office building, Germany
Architect: Kauffmann Theilig + Partner
Photo: Transsolar

Environmental Science Institute, Japan
Architect: Nikken Sekkei Ltd.
Photo: SS Tokyo Co, Ltd.

Office and conference centre, Denmark
Architect: KHR Architect A/S
Photo: KHR Architect A/S

Front page:
Office Maisema 2000, Finland
Architect: Kai Wartiainen
Photo: Jussi Tiainen
Office Bellevue, Netherlands
Architect: B&D Architects bv
Photo: NV Nuon
Office Grafenau, Switzerland
Architect: H. Bosshard & W. Sutter
Photo: H. Ege