IEA Solar Heating and Cooling Task 23 Presents:

Examples of Integrated Design

Five Low Energy Buildings Created Through Integrated Design

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

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Examples of Integrated Design

Five Low Energy Buildings Created Through Integrated Design

SHC Task 23: 'Optimization of Solar Energy Use in Large Buildings'

Austria
Canada
Denmark
Finland
Germany
Japan
Netherlands
Norway
Spain
Sweden
Switzerland
United States

AUGUST 2000

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

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1 Introduction

1.1 IEA, Solar Heating and Cooling Programme, Task 23

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 research & development 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.

In the framework of the IEA Solar Heating and Cooling Programme, 'SHC Task 23, Optimisation of Solar Energy Use in Large Buildings' was initiated.

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.

The main objectives of SHC Task 23 are to ensure the most appropriate use of solar energy in each specific building project for the purpose of optimising the use of solar energy and also of promoting more use of solar energy in the building sector. SHC Task 23 focuses primarily on commercial and institutional buildings.

1.2 Stories of integrated design

To start with, a selection was made of 21 existing buildings in twelve countries, which are good examples of integrated design and show several sustainable technologies. Of these 21 buildings five buildings are presented in this booklet as a showcase of how integrated design creates attractive, sustainable buildings. The booklet shows a primary school in Austria, an office building in Canada, an information centre in Denmark, an office building in Germany and a school in the USA. The story of each building tells how the design team managed the design process, traces work flows and the relations between the participants in the team and shows how the work resulted in an example of sustainable construction. A table of characteristic data is presented for each building.

2. Lessons learned

Throughout the design process of the five case story buildings, described in this booklet, several experiences were found to be noteworthy and useful for future design teams. The following is a survey of these so called lessons learned by the design teams of five case story buildings. The lessons are arranged by three topics (Team, Process and Techniques).

Team
- Co-operation between architect and engineers has to be very close right from the beginning to achieve good results.
- Close collaboration between the members of the design team is needed throughout a project, especially regarding the most innovative aspects and problems that emerge during construction, when quick decisions are necessary.
- Persistence on the part of the architect can result in success.
- Innovative design and construction require an extra effort on the part of even a very experienced construction team. Conflicts may result.

Process
- A design workshop at the start of the project greatly stimulates the development of common ideas on the design and the design process.
- It is advisable to make a guideline for dealing with conflicting goals (for example 'minimise energy consumption' versus 'optimise daylighting') and conflicting interests (for example client versus user).
- The integrated design process for the interdisciplinary planning process which was developed in the Canadian project is a valuable instrument.
- One should aim for optimum result, not just for the smallest common denominator.

Techniques
- An energy-efficient building can be built by using relatively non-exotic technologies applied in innovative and effective ways.
- Focus on the building shape, orientation, solar potentials and use before specific installations are considered.
- Implementing products that still have to be designed requires a lot of extra time.
- The most sophisticated technical equipment is of no use if it is not comprehensible.
- Careful design of a daylighting system saves energy, realises an agreeable working climate and leads to improved student performance.

3. Case Stories

Austria
The challenge to design an 'ecological' building in co-operation

Canada

Integrated design works in a competitive market

Denmark

Create a building as an example for 'our common future'

Germany

An atmospheric office

USA

Student performance improved by daylighting

Münchendorf Primary School, Austria	School building
Architect	Arch. Mag. Ing. Helmut Deubner, Gänserndorf Süd
Project manager	Arch. Dipl. Ing. Heinrich Schuller, Vienna
Engineers HVAC	Ing. Peter Trenkler, Münchendorf
Engineers Energy/Comfort	Dipl. Ing. Roland Phillip, St. Andrä/Wördern
Latitude	48° North
Climate type	Moderate
Heating degree days	3322 (base is 20/12°C)
Cooling degree days	-
Building costs	1,205 US dollars/m^2
Total floor area	1,824 m^2 (gross)
Heated surface	1,824 m^2 (net)
Insulation	U-value [W/m^2K]:
Walls	0.35
Roof	0.18
Windows	1.40
Total solar energy transmission	60%
Annual energy consumption	90 kWh/m^2 (gas) plus 12 kWh/m^2 (electricity)
Applied technologies	Low-temperature radiant wall heating (classrooms), ceiling radiant heating (gym), extra glazing, glazed conservatory, 16 m^2 solar collector on gym to supply hot water showers, roof windows, energy efficient lighting, daylight dependent control system of artificial lighting use of natural materials
Further information	ATOS Arch. Dipl. Ing. Heinrich Schuller Wickenburggasse 26/4 A-1080 Vienna Phone: +43 1 4059310-12 Mag. Arch. Helmut Deubner Hochwaldstrasse 37/5a A-2230 Gänserndorf Süd Phone: +43 228270289-0

3.1 Austria: The challenge to plan an ’ecological’ building in co-operation

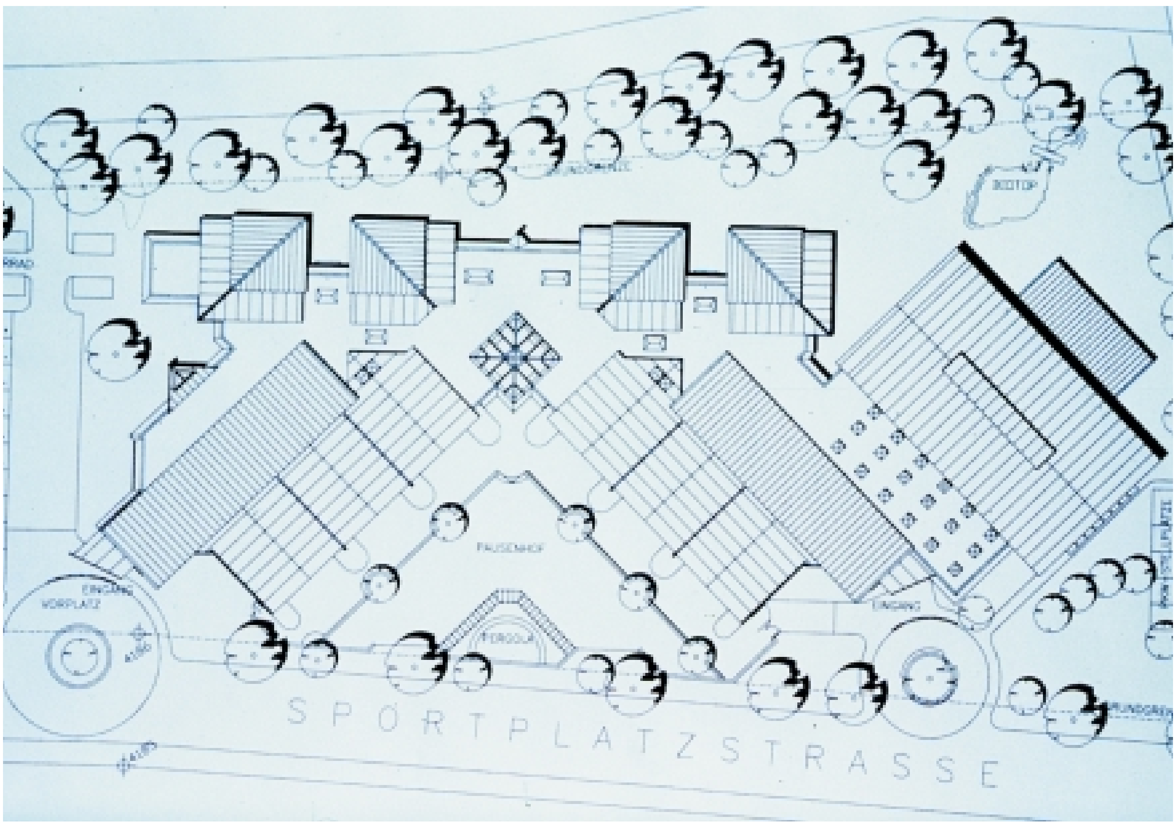
The deceptive charm of freedom in design does not necessarily meet with the steeplechase of regulations, abilities and good will. When guidelines are not at hand, clients, designers and users can already have difficulties when deciding which materials and principles should be applied in an 'ecological' building. Conflicting goals may complicate the process even more. However, much can be achieved by close co-operation. In Münchendorf, Austria, all partners concerned successfully took up the challenge to build an ’ecological’ primary school.

Münchendorf lies in the province of Lower Austria. When the local authorities contracted architect Helmut Deubner to take charge of the designing and construction process of the new primary school, their goals were rather vague. In general the building should meet high standards as to indoor environment and the use of ecologically agreeable materials. The notorious 'sick building syndrome' should be avoided.

As to energy the building should function more efficiently than a conventionally built school. However, no more detailed specifications to energy and environmental aspects were given. The only restriction was that the costs should not exeed more than ten percent of the usual building costs. Since the local authorities of the village Münchendorf are responsible for the running energy-costs, it is of even greater importance that these are kept low.

Comparing different concepts
Already before the architect was commissioned, the community had decided to situate the school on the outskirts of the village close to an existing sports ground. A specific room programme was given. It provided nine classrooms, one central cloakroom, offices, sanitary rooms, a gym etc. From the start it was evident that it had to be an 'open' school, providing green space as well as maximum energy efficiency.

The architect presented two completely different concepts and discussed them with the advisory council. This council consisted of representatives from local and governmental authorities: the mayor, the council for finance, technical authorities from the regional government, the school director and the architect.



Picture 1 - The plan shows free standing exposure and noisy environmental conditions due to the location next to the main road.

Project Work Flow — Primary School, Münchendorf, Austria

Activities / Information / Inputs / Outputs / Decisions / Evaluation / Results / Impacts / Effects

What ? - Project related activity
Who ? - Actor responsible
How ? - Examples, use of methods / Tools

Input on .....
Interrelation
Iteration loop
Restriction

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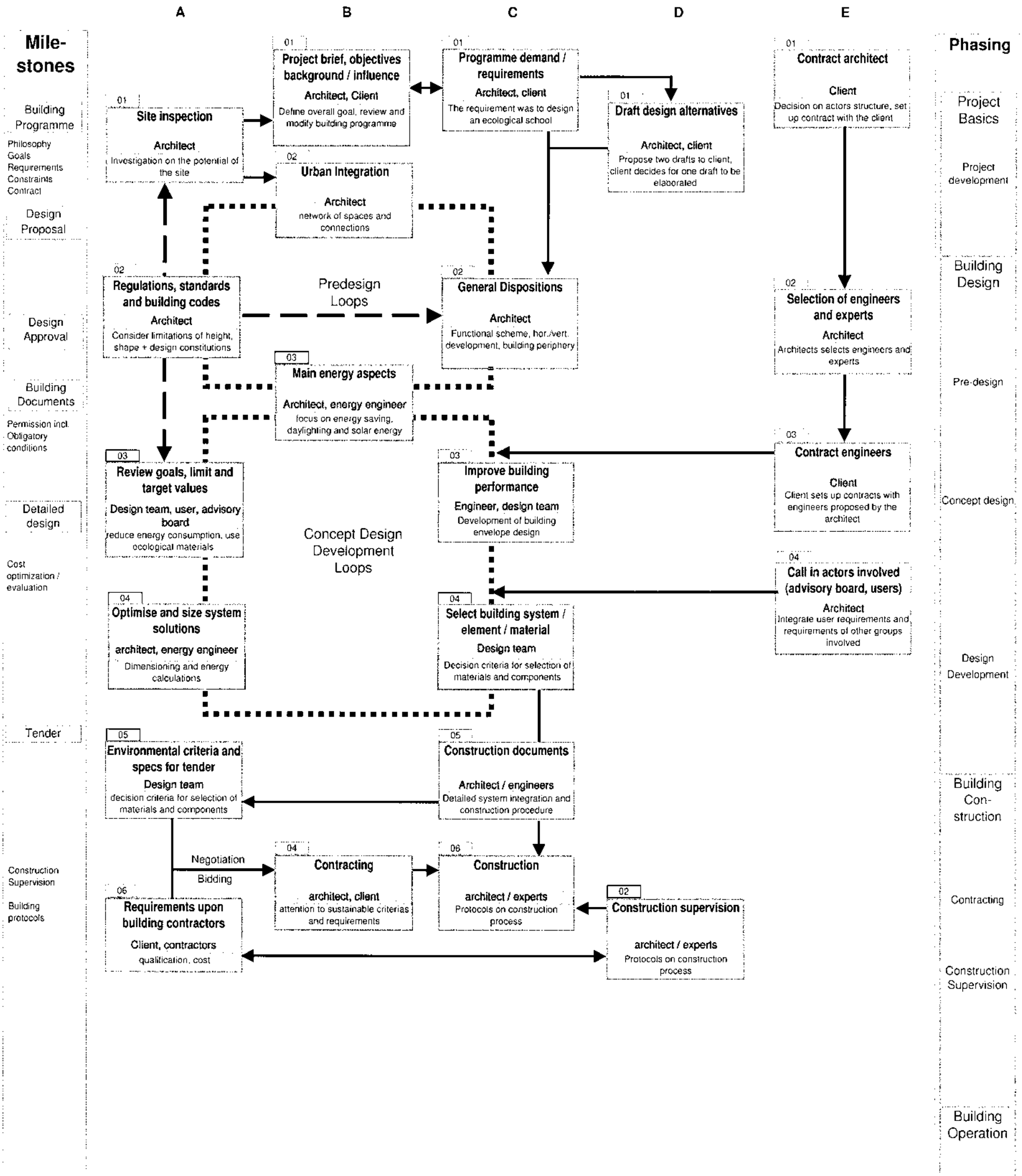


3 / 2000 sol·id·ar Dr. Günter Löhnert, Forststrasse 30, D-12163 Berlin, *phone* +49-30-8270 419-0, *fax*: -2, *e-mail*: solidar@t-online.de

The first of the two said concepts, a somewhat futuristic design, envisioned a long glass-roofed building with the classrooms inserted like massive cubes. The board was quite convinced that this concept would result in a high energy consumption. It would have been too costly for the architect to convince the board of this building concept by elaborate energy simulations. Therefore this 'experimental' concept was discarded in favour of the second, more conventional, concept, which was based on known figures as to energy. Characteristic elements in this concept were the use of environment-friendly materials only, the highest possible use of daylight and natural ventilation. Calculation of heating energy demands followed the Austrian Standard ÖNORM 8110.

Listening to the users voice in ecological building

The architect started to interview the teachers with the aim to integrate their know-how, their experience and their ideas. The teachers opposed some of the characteristic elements of the concept. For instance, a natural green and daylit recreational room under a glass pyramid was planned. But the teachers objected: water and plants would give trouble with dirt and control. The architects stout opinion that plants and their maintenance are an important means of education within the comprehensive planning of a school did not convince them.

On the other hand, they preferred by far - almost enthusiastically - the architect's concept of a cloakroom for every single class. In order to meet modern educational principles - regarding teamwork for instance or even more avant garde the 'Kuschelecke' (hugging corner) - the layout of the classrooms became quite unconventional. Once the concept was accepted, it was developed by a team consisting of the architect and engineers for energy and construction design.

Guideline questions for decision making

Communication among so many partners is not always easy. Lack of understanding is resulting from the fact that non-professionals and technicians use different languages. Throughout the process various alternatives had to be evaluated and agreed upon. However, in his responsibility for the budget the architect had the authority to decide. Complicating matters were the lack of ecological knowledge and experience with ecological building on the part of the governmental representatives. Often trade-offs had to be made. Such as: energy savings technology versus cost efficiency or easy handling, energy conservation versus daylit space. And finally: building costs versus operating costs.

In case of competing options, the team held on to three guideline questions:
1) Which criteria are the most important?
2) Which are met by one option only?
3) Which are met by more than one option?

Technology follows function

Aiming at a high ecological standard at low cost, the architect used sophisticated architectural design rather than elaborate technology. Passive solar use had to cope with the technical devices in order to be understood by the user and to be managed easily by the technical operator.

The bearing walls consist of plastered hollow bricks with 8 cm cork insulation outside, as the most cost effective material. The clay-tiled roof is a wood construction. Remarkable is that vapour barriers between the roof and the insulation layer were not necessary because of the use of cellulose insulation. In the classrooms wooden covering, in other rooms a combination of wood and gypsum fibre boards were used. The classrooms have wooden floors.

Resources used
1) The Swiss guideline for the design process TOP
2) Own software sheets for calculating heating demands

At present new simulation programmes are used: WAEBED (daily heating losses and heating demand), KENN 8110 (overheating in summer), TELPHYS (U-values and sound insulation) and SHW (dimensioning solar collectors).

Low energy consumption
All occupied spaces are lit by daylight. Non dazzling roof windows provide extra daylight from above. Central showpiece is the 'conservatory' under the glazed pyramid. All lightings are regulated by electronic daylight sensors.

Both passive and active solar energy technologies are used. Passive through south oriented windows in the classrooms and the corridors. Active with a 16 m^2 solar collector on the southern wall of the gym to heat the water for the showers. The comparatively costly solar water heating was felt to be justified when considering that in an 'ecological' building a solar collector is a must. Moreover the mayor wanted to give an ecological example.

Windows are situated in such way that adequate natural ventilation in the classrooms is secured. In the gym an additional mechanical ventilation system with heat recovery had to be installed, although natural ventilation would have been sufficient. The heating system is based on a gas-fired condensing boiler, using low-temperature wall radiators to improve the energy efficiency. In order to avoid injury and pollution the radiators are placed under the wall surface. Blinds, lighting, heating and ventilation are individually controlled by the user.
As a result the total energy demand is low when compared to conventional building.

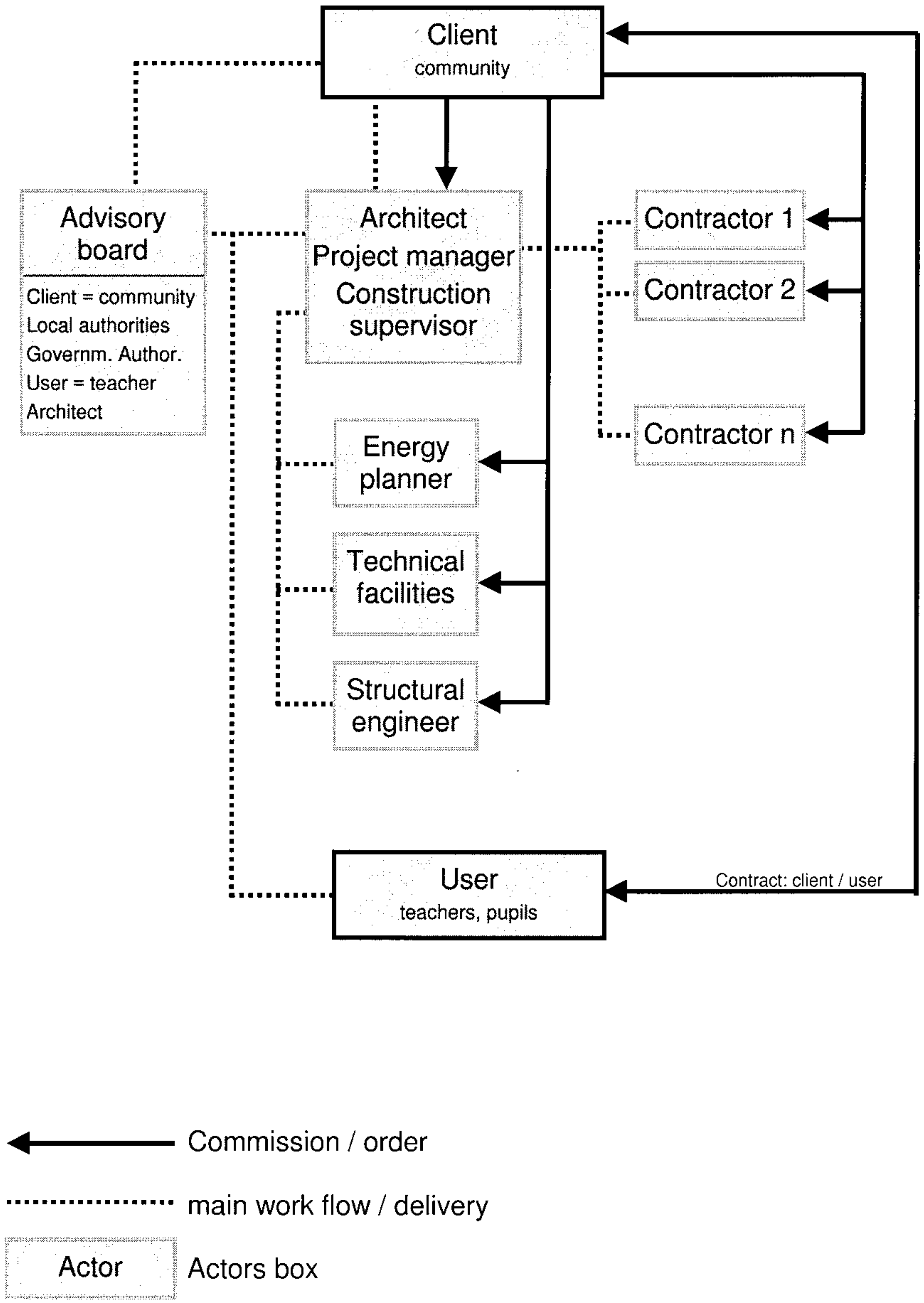
Getting used to it
No PVC was admitted in the construction. Wall painting was done with natural paint. Water coming down the gutter is seeped directly into the ground, thus supplementing the ground water supply. Because of the high ground water level, the water to flush the toilets and irrigate the green spaces comes from a well. Also water saving fittings and flow controllers are used.

Although occupants had to get used to operating the heating system and to treating the floors with resin and wax, both the teachers and the pupils are quite satisfied with their new school.

Lessons learned
- Co-operation between architect and engineers has to be very close right from the beginning to achieve good results.
- It is advisable to make guidelines for dealing with conflicting goals (for example minimise energy consumption versus optimise daylighting) and conflicting interests (for example client versus user).
- The most sophisticated technical equipment is of no use if it is not comprehensible.

Picture 2 - South oriented classroom windows facing the recreation yard.

Actors Relation Chart — Primary school, Münchendorf, Austria



Crestwood 8, Richmond BC, Canada	Office building
Architect	Bunting Coady Architects, Vancouver
Engineers HVAC	VEL Engineering, Vancouver
Engineers Energy/Comfort	D.W. Thomson Consulting ltd., Vancouver
Latitude	49° North
Climate type	Coastal temperate
Heating degree days	3030 (base is 18°C)
Cooling degree days	-
Building costs	512 US dollars/m^2
Total floor area	7,444 m^2 (gross)
Heated surface	7,192 m^2 (net)
Insulation	U-value [W/m^2K]:
Walls	0.38
Roof	0.28
Windows	1.76
Total solar energy transmission	UNG=0.33
Annual energy consumption	95 kWh/m^2
Applied technologies	Extra glazing, use of recycled materials and materials with low embodied energy, two-cell parabolic fixtures, Building Management System
Further information	Canmet Energy Technology Centre Nils Larsson 13/F, 580 Booth St. Ottawa, KIA, OE4 Canada Phone: +1 613 769 1242

3.2 Canada: Integrated design works in a competitive market

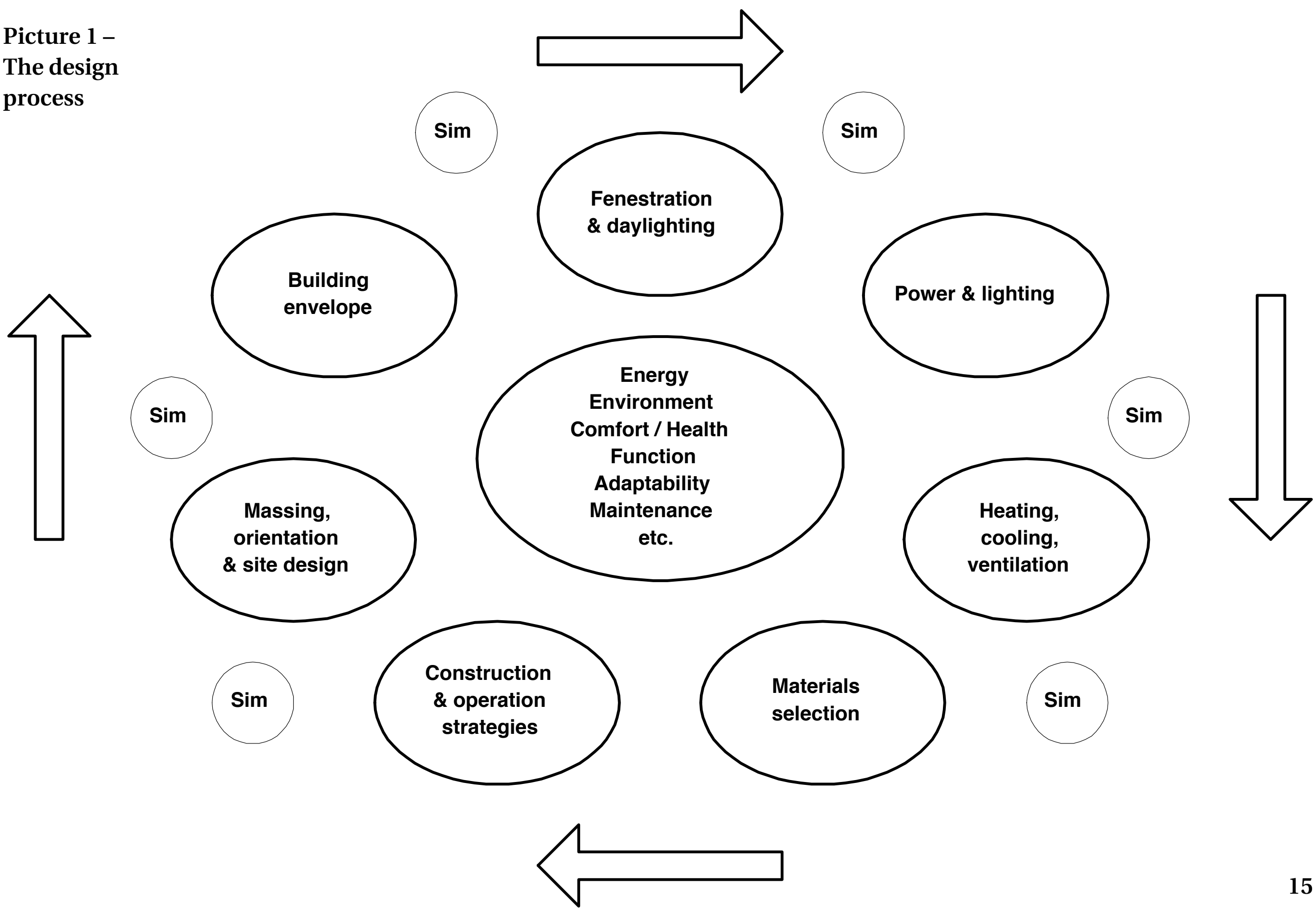
In a suburban office park in Richmond, Canada two three floor office buildings stand side by side: Crestwood 7 and 8. Alike in looks as they may be, and with comparable building costs, number 8 is about 30% more energy efficient than the adjacent no. 7, and is about 50% better than comparable conventional buildings. Likewise, the amount of waste during construction and operation was reduced by fifty percent. What is even more: the integrated planning process has been used by others since.

Crestwood 8 was conceived as a new speculative office building in an office park in Richmond in the Canadian province of British Columbia. The clients' major need was a building that would match existing buildings on the site (Crestwood 7), both in appearance and in building costs.
From an environmental point of view the project had a good start. The project manager, representing the developer and the owner, was an architect with an interest in energy. In exchange for funding the clients agreed that it would be worthwhile to conform to the Canadian C-2000 performance requirements. C-2000 aims at 50% energy performance improvement over existing good practice, and has demanding requirements in other areas of environmental performance.

Planning process
In Richmond, building an office according to C-2000 standards was a new feat, and it was also the first building designed according to requirements of the C-2000 program.
In order to fit the environmental objectives to the clients' original need, an integrated planning process was clearly needed. For instance: it became evident that the gap between the architect and engineers would have to be narrowed before any real progress in building efficiency could be made.

An interdisciplinary design team was formed, including mechanical, electrical and lighting engineers. Also, an energy specialist and a C-2000 representative were added to this team. Right from the beginning of the concept design phase, all team members were involved in all meetings. The architect took a lead role in the integrated design process, using the C-2000 requirements as a starting point.

Picture 1 – The design process



Critical information regarding the energy budgeting, client parameters, site restraints and basic technical information was exchanged. Each member of the group was made aware of every other member's concerns and ideas, and contributed equally during the concept design process. At several points in the process, but especially in the early stages, the contributions made by the C-2000 representative were invaluable, like the introduction of a daylighting expert and an energy simulator to the team. The energy simulator served a key role in providing continuous feedback (using DOE 2.1E) on the performance levels being reached.

One of the results of the project was the development of an eight-step integrated design process based on the process requirements within the program. Later on, this process was developed into a Quality Assurance Program for the local utility, B.C. Hydro.

Investigate and choose
Initially, the biggest challenge the team had to face was to sample, and to simplify the existing wealth of research on energy efficiency and environmentally friendly materials and then to incorporate this knowledge into the project.

The first activity of the project team was the preparation of several different exploratory concept designs, that were investigated to the extent of preliminary energy simulations. The alternatives involved different orientations of the building, percentages of fenestration and assumptions of glazing efficiencies and mechanical system types and performance.

Budget constraints
The draft performance target reports were discussed in the team and with the clients, which resulted in a choice of one design. On this selected design several DOE 2.1E energy simulations were carried out. When the team was ready to begin contract documentation, the performance and cost of the C-2000 design were compared to the conventional design.

At this point, a few chosen systems unfortunately had to be downgraded to meet budget requirements. Therefore, the project team eliminated features such as fibreglass window frames in favour of cheaper thermally-broken aluminium frames. However, this substitution only had a 1% effect on overall performance. The rest of the process followed a conventional path. In the end a two-year monitoring process still was commissioned under a separate contract.

Resources used
1) Performance planning and targeting reports (forced consideration of alternatives)
2) DOE - 2.1E for energy simulations
3) EMPTIED software used to test vapour diffusion potential
4) ASTM tests used for air barrier testing and ventilation

The tools were used as a help in the design process and resulted in an upgrade of window and glazing design.

Solar and lighting
Very many options for solar energy use, lighting efficiency and energy efficiency were investigated. Active solar energy systems were struck off the list, due to the high costs and the desire to match the appearance of existing buildings. Moreover, solar energy systems were contrary to the over-riding goal of maintaining simplicity in operation. For thermal solar energy the low thermal loads did not portend a favourable economic return. Passive solar energy and lighting however proved to be suitable. To maximise solar heat gain during winter conditions and daylighting potential throughout the year, the percentage and location of glazing was adjusted.

In order to learn more about lighting and daylighting alternatives the project team visited Seattle Lighting Laboratory. Subsequently, sections of the roof and walls were drawn up to investigate the effect of exterior only and interior-exterior combination light shelves. Options for a higher ceiling, clerestory and skylighting were reviewed. Several options were investigated for energy efficient lighting, and finally deep two-cell parabolic fixtures were chosen.

Energy efficiency
Energy efficient measures were reviewed for applicability and costs. Instead of innovative high-tech, the chosen options include a wide range of relatively non-exotic technologies applied in new and effective ways. Low-emission double glazing, 4-pipe fan coil systems, mechanical ventilation with heat recovery and computer based energy use control, to name but a few. One of the remarkable

Project Work Flow   Bentall Crestwood 8 Building, Vancouver, Canada

Activities / Information / Inputs / Outputs / Decisions / Evaluation / Results / Impacts / Effects

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How ? - Examples, use of methods / Tools

Input on .....
Interrelation
Iteration loop
Restriction

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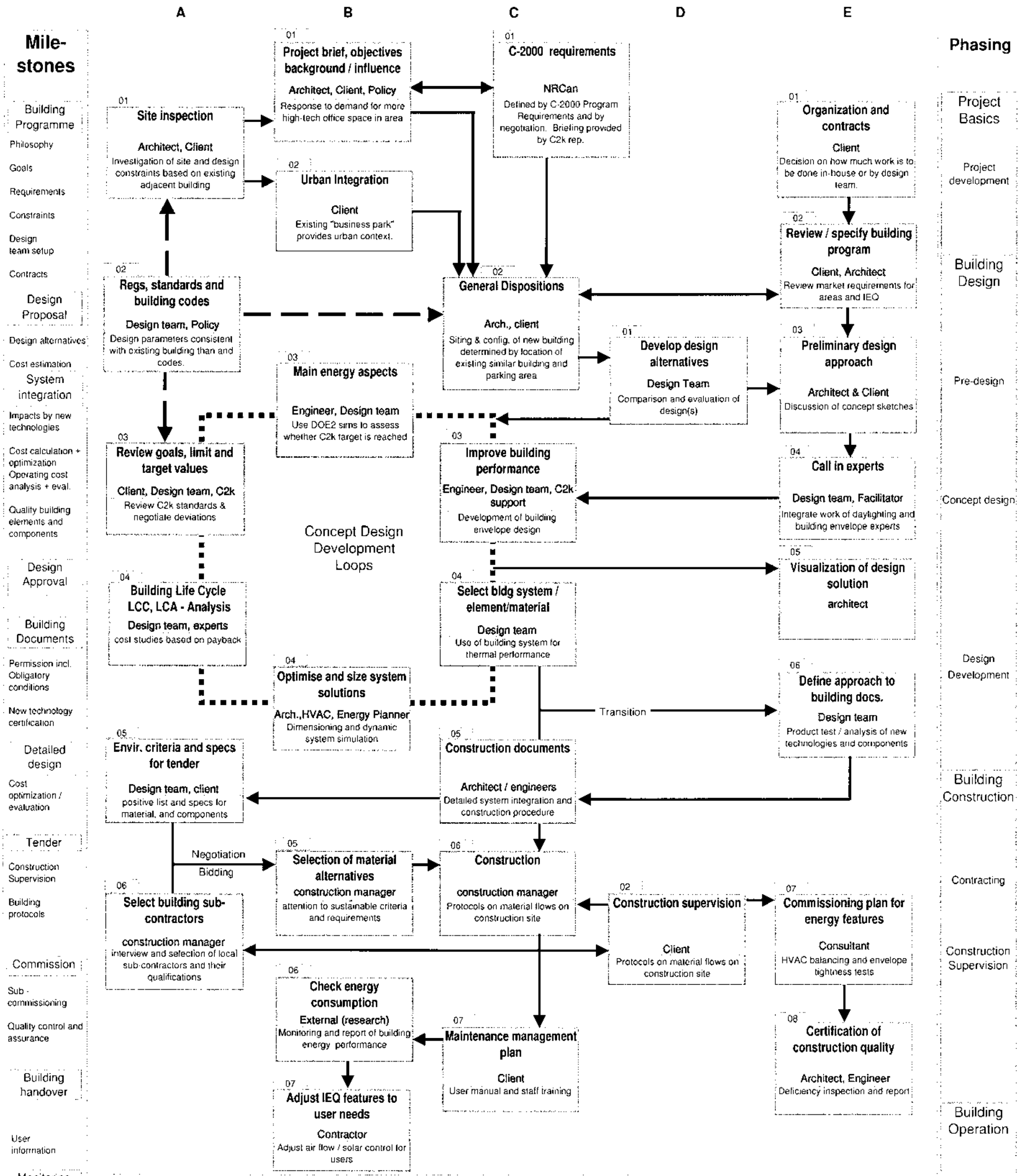

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outcomes of the project was, that even with these more or less conventional technologies, it was possible to realise the Canadian C-2000 performance levels. New techniques such as three pane argon filled glass turned out to result in negligible overall performance improvements.

Environmentally sound measures
Environmentally sound building measures were considered and implemented. Whenever feasible, recycled material and materials with low embodied energy were used. The structure is concrete tilt-up which minimises wooden form work and is expected to last a hundred years. Gypsum board and ceiling tile have a high recycled content. The floors in most service areas are sealed concrete rather than vinyl tile.
During construction, a recycling program was carried out including requirements for supplies and materials and services. All cardboard, wood, glass and drywall were recycled on site. Form work was reused where practical. Recycled crushed concrete was used as an asphalt sub-base instead of gravel. Excess roof ballast was recycled as drainage material.

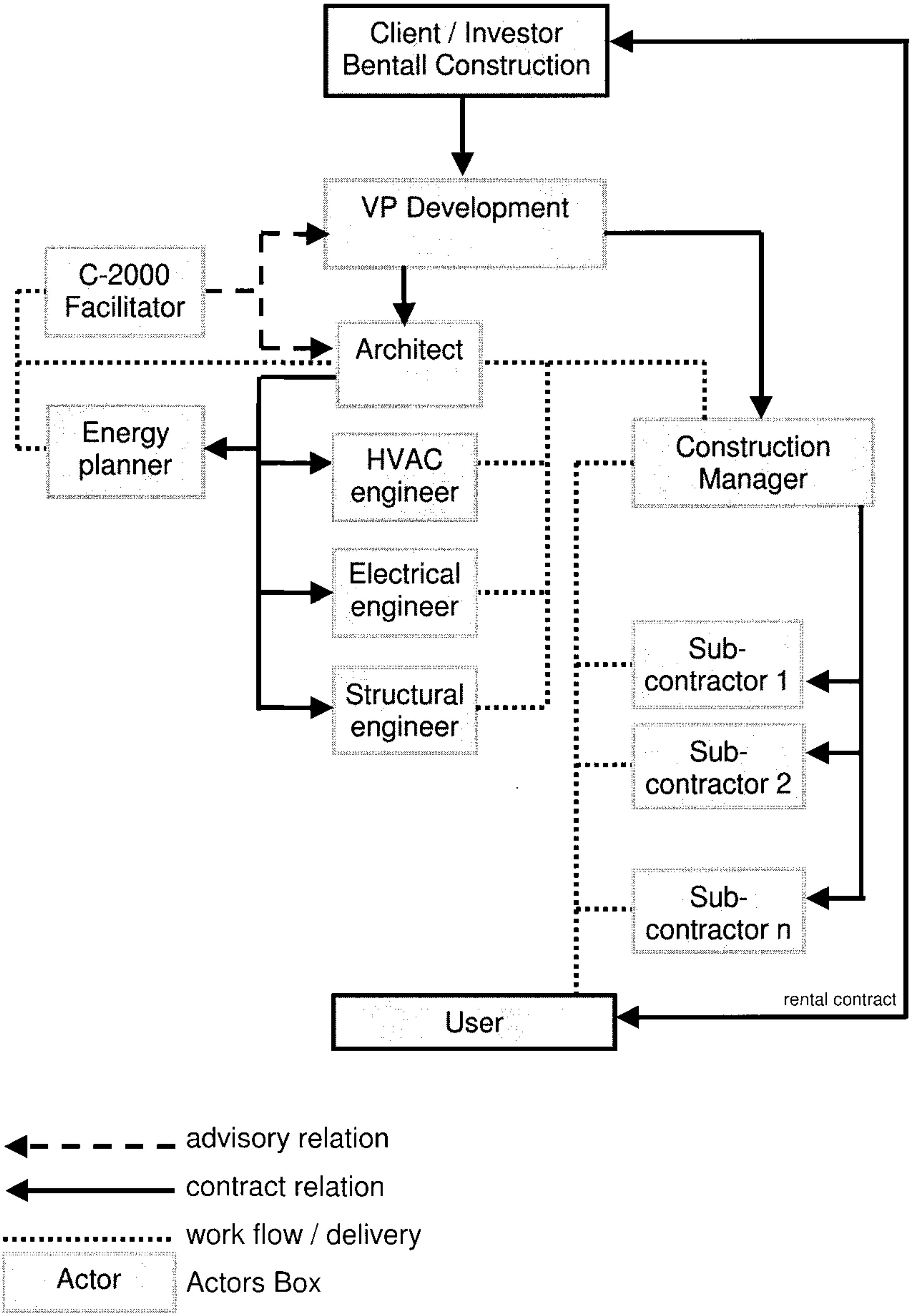
Satisfaction
Tenants of Crestwood 8 were asked to fill out occupant assessment surveys. The results were compared to the results of identical surveys given to users of the adjacent building Crestwood 7 that has similar dimensions but has not been built to C-2000 standards. The results show that employees in Crestwood 8 gave their workplace a higher rating in terms of overall building impression. They also rated their building to be less noisy and have better indoor air quality. Finally it turned out that they have a better overall impression of their building environment.

The developer's satisfaction can be deduced from the follow-up in Crestwood. He subsequently built another office building on the site, including many of the features of Crestwood 8, this time even without any government subsidies. The tenants were attracted by the fact that Crestwood 8 is a 'green building', which helped in leasing in a soft market.
For the project team building an office to C-2000 standards was something new. The fact that all engineering consultants were involved from the beginning was unusual, but a very positive experience for all of the participants.

It should also be noted that this building, along with two other C-2000 projects in the province, has, according to independent consultants, changed the design culture in the region.

Lessons learned
- The integrated design process for the interdisciplinary planning process which was developed in this project is a valuable instrument.
- An energy-efficient building can be built by using relatively non-exotic technologies applied in innovative and effective ways.

Picture 2 - Front view of Crestwood 8


Client / Investor
Bentall Construction
VP Development
C-2000
Facilitator
Architect
Energy
planner
HVAC
engineer
Electrical
engineer
Structural
engineer
Construction
Manager
Sub-
contractor 1
Sub-
contractor 2
Sub-
contractor n
User
rental contract
advisory relation
contract relation
work flow / delivery
Actor
Actors Box

Denmark: Create a building as an example for 'our common future'

The Brundtland Centre, Toftlund, Denmark	Exhibition centre and office building
Architect	KHR Architects, Virum
Engineers	Esbensen Consulting Engineers, Sønderborg Slot Møller Consulting Engineers, Sønderborg
Latitude	55° North
Climate type	Northern coastal
Heating degree days	3014 (base is 17°C)
Cooling degree days	0
Building costs	1,376 US dollars/m^2
Total floor area	1,800 m^2 (gross)
Heated surface	1,450 m^2 (net)
Insulation	U-value [W/m^2K]:
Walls	0.3
Roof	0.2
Windows	1.4
Atrium roof	1.6
Total solar energy transmission	60%
Annual energy consumption	60 kWh/m^2
Applied technologies	Glazed atrium, thermal solar energy system, reflective blinds in window panes and reflective ceilings, lighting control system, low-e fluorescent tubes, low-temperature heating, Building Management System, PV cells integrated in the sealed glazing of the atrium roof and in standard panels at the south east facade, rainwater storage system, environmental sound materials.
Further information	Esbensen Consulting Engineers Vesterbrogade 124B DK-1620 Copenhagen V Tel. +45 33 26 73 00

3.3. Denmark: Create a building as an example for ‘our common future’

Building an information centre in Brundtland City, the world's first town to demonstrate the principles of 'Our Common Future', can only stimulate designers to make every effort to come up with a striking creation. In Toftlund, Denmark a cross-disciplinary planning team engaged in an integral planning process. For the Brundtland Centre even totally new products were developed.

As a result of the recommendations in the UN report 'Our Common Future', under the chairmanship of Norway's former prime-minister Brundtland, in 1987 the Danish government invited Danish municipalities to forward suggestions as to how they might become a Brundtland City. A city, that is, that could demonstrate an overall fifty percent saving in energy. A city also - to name just a few issues - where citizens and companies use environmentally sound products, sort their waste and travel by bike or public transport as much as possible.
Toftlund, the main town in Nørre Rangstrup municipality was elected to become Denmark's new Brundtland City. Naturally, an information centre was needed that would collect and disseminate all the lessons learned regarding the envisaged sustainable society to the general public.
The Brundtland Centre would get a lecture hall, seminar rooms, an exhibition space, an atrium (also used for exhibitions) and an office wing, used by permanent staff of the centre and by companies renting space there.

Of course, the Centre itself should embody principles of sustainability, the design including (as ‘Our Common Future’ demanded) a fifty percent improvement in energy efficiency, when compared to the norm of building traditions in Denmark. Furthermore the Centre should be a working exhibition of energy saving elements such as daylighting systems integrated in sealed glazing, building integrated semi-transparent photovoltaics providing solar shading and an atrium for utilisation of passive solar energy.
Additional goals were to visibly use environmentally sound building materials and to realise high levels of indoor comfort, all to be achieved within certain budget restraints. For the innovative elements the client signed a contract with the EU Joule Solar House programme, that would subsidise the project substantially.

Planning workshop
Because of the many technical and overall constraints these ambitious goals posed on the design a cross-disciplinary planning team was set up. The team agreed on a shared responsibility contract, where the responsibility for quality, economy and durability was taken by all, (architects and engineers alike). But whereas building design teams are usually co-ordinated by the architect, this time, because of the technical complexity of the building, the team was initially led by the engineering company responsible for the constructions. Later on, when construction started, the leadership was shifted again: to an engineer with an installations background, since the co-ordination on site primarily concerned building installations.

The design work began with a two-day design workshop, in which all team members participated. Subjects were discussed like building performance criteria, planning constraints, building design options, daylighting design, PV systems, ventilation and indoor climate, the overall energy optimisation of the building, detailing and project planning. The workshop moved the project forward dramatically compared to the standard working method. From that point onward, the planning process of weekly meetings could proceed along normal lines in building project design. Gradually the focus descended from overall problems to minute details in the final stage.

Better no ‘high-tech solutions’
Earlier, the design team's general technical concept and design of the Brundtland Centre had come out winner of the EU competition 'Working in the city'. The design of the energy system was based on the overall strategy that wherever the building itself could provide the necessary indoor climate and energy saving facilities, this would be preferred to 'high-tech solutions'. Whenever a more technical solution was required for lighting, fresh air, etcetera, the team aimed to develop solutions which were as generally applicable in other buildings as possible.

A wide variety of energy measures was examined using different design tools in order to get an understanding of these measures in relation to the building. Discussing the planned atrium roofing took up most time due to the large number of relevant parameters, such as shading effects on PV cells, solar shading needs of the atrium, size and shape, mounting techniques, snow, cleaning and maintenance etc. Another critical point was the horizontal division of the 'Energy Facade'. In the first months the facade was divided in three lines: the upper line of daylight windows, a middle line of vision windows and a parapet of translucent photovoltaic modules. Then, at a relatively late stage, fire rescue openings were specified as being necessary and from an architectural point of view the three-band design could not be made into an aesthetically appealing solution. Above the parapet an extra horizontal band had to be added with normal manual windows and a rescue window in one line.

Other measures that were taken, apart from the measures that were prescribed by the client, include a low-temperature heating system, with a floor heating system at ground level and low temperature radiators on the first floor. The use of daylight was optimised by integrating reflective blinds between the window panes, directing diffused daylight onto the reflective ceiling and far into the rooms. The reflective blinds can also act as shading when closed. For energy efficient lighting low-e fluorescent tubes were installed.
Active thermal solar energy systems were installed for exhibition purposes. The generated heat is delivered as domestic hot water to the little restaurant in the centre. Environmentally sound measures include a collecting system for rainwater from the roof, which feeds an underground storage. The water is used for flushing toilets, watering of plants and cleaning. Materials that cause a bad indoor climate through emission of solvents or special cleaning requirements were avoided. Instead such materials as tiles, concrete, wooden floors, glass and aluminium were used.

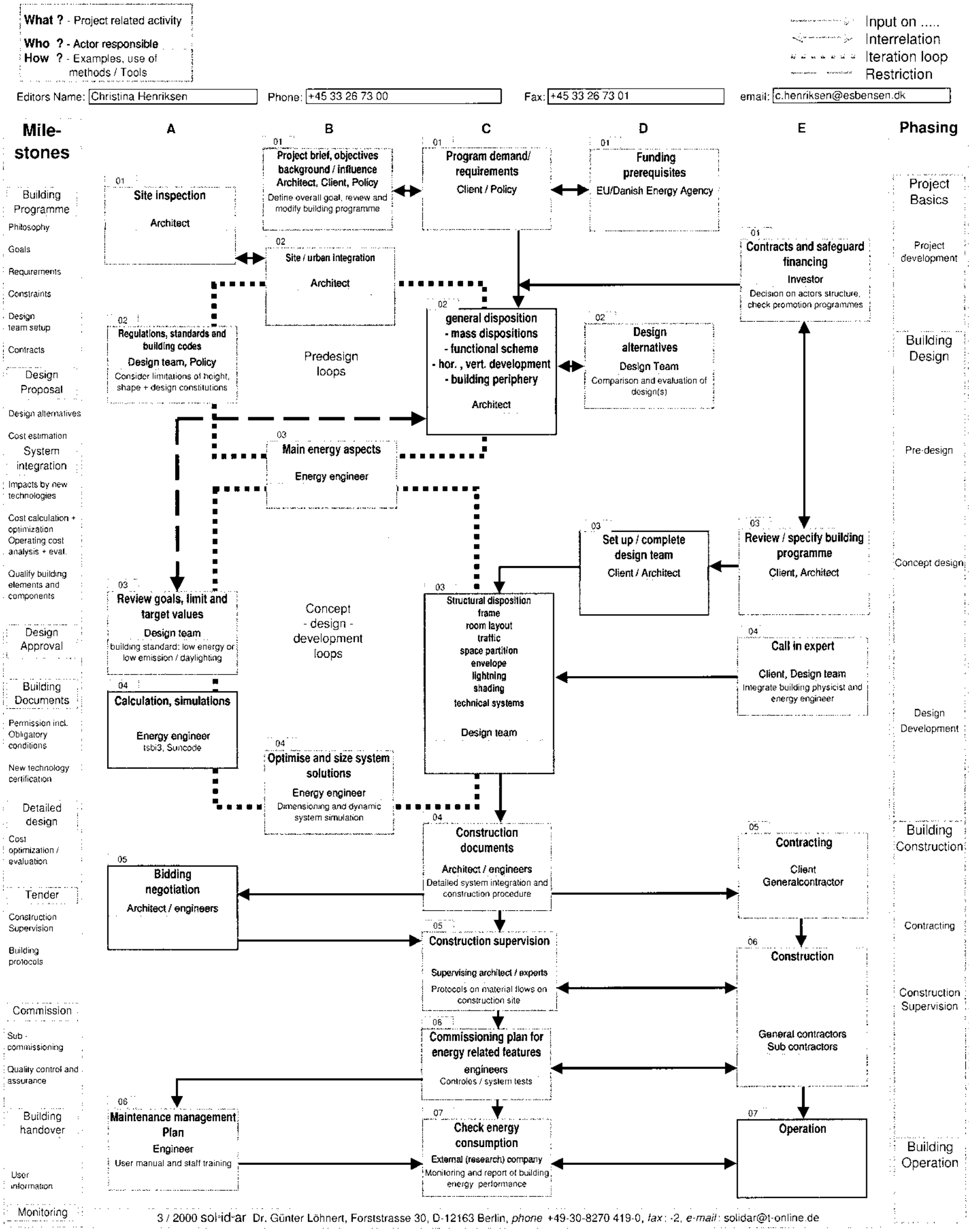
Lessons learned

- Close collaboration between the members of the design team is needed throughout a project, especially regarding the most innovative aspects and problems that emerge during construction, when quick decisions are necessary.
- Implementing products that still have to be designed requires a lot of extra time.
- A design workshop at the start of the project greatly stimulates the development of common ideas on the design and the design process.
- Focus on the building shape, orientation, solar potentials and use before specific installations are considered.

Picture 1 - General view of the Brundtland Centre The atrium in the centre of the building has a free vertical facade towards south west and a shed (slanting) roof. Integrated on the south oriented part of the roof are semi-transparent photovoltaic panels. The atrium has direct connections to almost all other rooms, which is an important feature for the ventilation strategy of the building.

Project Work Flow — Brundtland Centre, Toftlund, Denmark

Activities / Information / Inputs / Outputs / Decisions / Evaluation / Results / Impacts / Effects



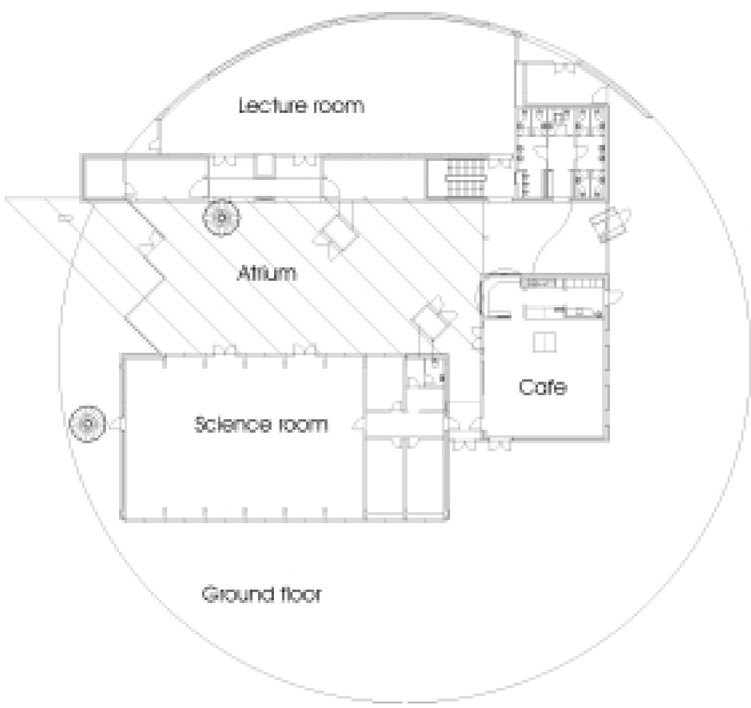
Efforts
Quite a few entirely new elements had to be designed and included in the building. The main obstacle was to find manufacturers able to produce these elements in good quality. Some completely new products had to be invented. The design team largely underestimated the efforts needed to go through all the different stages of design, feasibility analysis, lab-testing, production start, test production and final delivery of these products. The major problem has been the production of the special windows with daylighting systems for the 'Energy Facade'. The company that was hired originally turned out to be totally in breach of contract and on the whole caused over one year's delay. A constellation of two new companies finally developed and produced the windows, but with a delay of two years.
Due to the lack of special windows finally, as a temporary solution, only a single glazing was installed with a U-value of 5 times the glazing planned for. In combination with a lack of solar shading this glazing caused overheating in summer and draft problems in winter. Now that the new special glazing has at last been installed, these problems are solved.

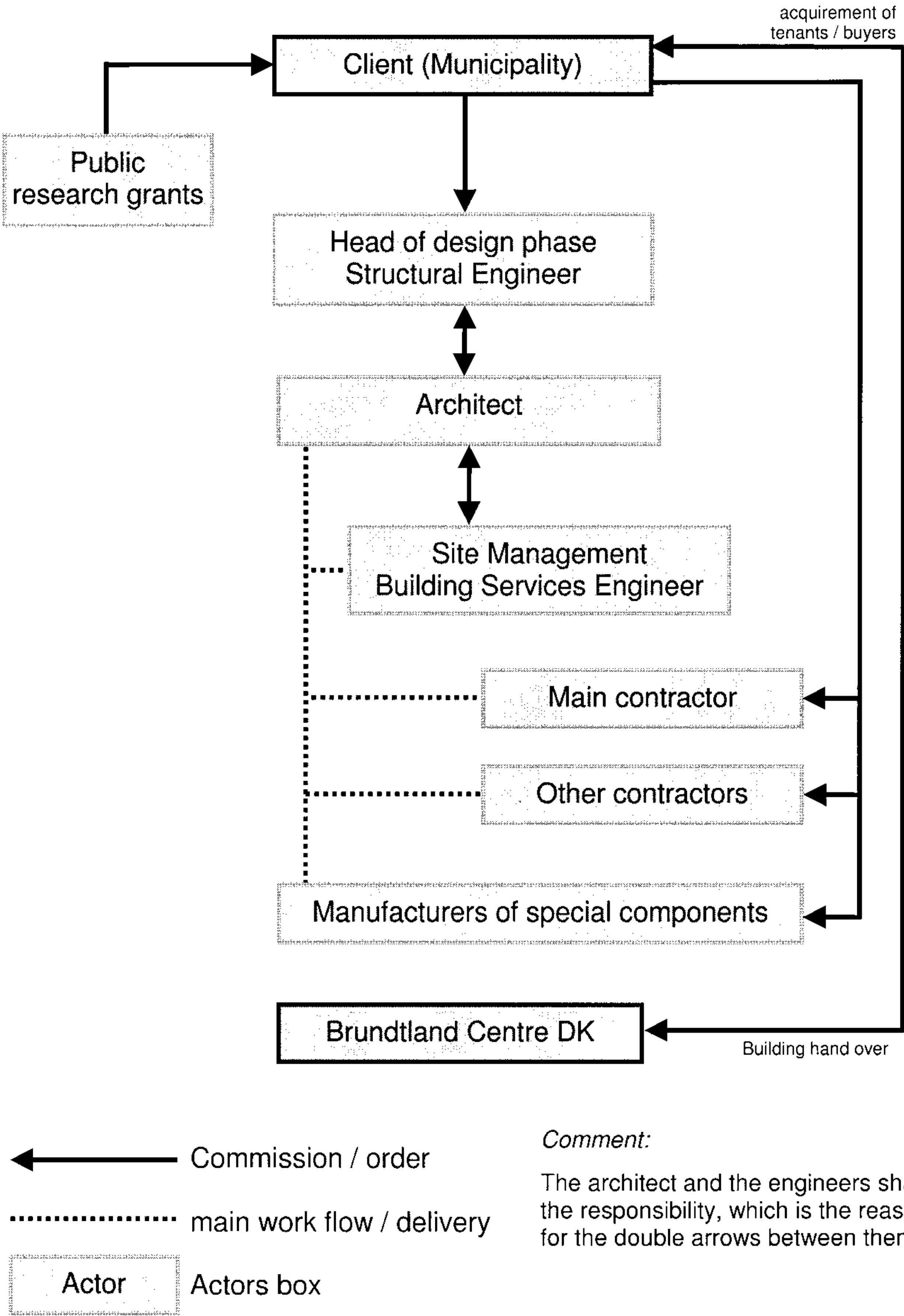
The option chosen for the central building management system (BMS) would not be the engineers choice today. The BMS was regarded a must for building up, for a well-functioning control strategy and to enable continuous collection of data for statistical analysis of the building's performance. Therefore the system designed is unusually large. The lay-out was a traditional one, based on star-shaped wiring, with one pair of wires per control point. If constructing the building today a bus-system would have been installed instead, giving a much simpler, more flexible and cheaper wiring with the same possibilities for monitoring and control.

Icon
The scope of the centre has been widely acknowledged in Denmark. The centre now serves as an icon for other building designers. Especially the indoor climate and the message to the designers to focus on the building shape, orientation, solar potentials and use, before specific installations are considered, has been a topic for discussion for all visiting design professionals.

Resources used
1) LT-method (thermal)
2) tsbi3 (thermal)
3) ESP-R (thermal)
4) Radiance (daylight)
5) Workshop
6) Bartenbach LichtLabor (lighting measurements)
The LT-method, the workshop and Bartenbach were used early in the design phase whereas tsbi3, ESP-R and Radiance were used rather late. ESP-R and Radiance were primarily used for evaluation of the project and for further analysis after finishing the building.

Picture 2 - Floor plan of ground floor (KHR Architects, Virum)





Comment:

The architect and the engineers shared the responsibility, which is the reason for the double arrows between them.

WAT, Karlsruhe, Germany	Office building
Architect	Architekturbüro Günther Leonhardt, Stuttgart
Engineers HVAC	Engineering office Werner Griesinger, Stuttgart
Engineers Energy/Comfort	Transsolar Energietechnik GmbH, Stuttgart
Latitude	48.9° North
Climate type	Middle European
Heating degree days	3409 (base is 15°C)
Cooling degree days	-
Building costs	1,000 US dollars/m^2
Total floor area	3,124 m^2 (gross)
Heated surface	1,900 m^2 (net)
Insulation	U-value [W/m^2K]:
Walls	0.242
Roof	0.167
Windows	1.1
Total solar energy transmission	52%
Annual energy consumption	80 kWh/m^2 (55 kWh/m^2 for heating and 25 kWh/m^2 for electricity)
Applied technologies	Facade integrated solar collectors, solar chimney wall, photovoltaics, convectors, floor integrated air ducts, light shelves, daylight switches.
Further information	Transsolar Matthias Schuler Curiestrasse 2 D-70563 Stuttgart Phone: +49 711 67976 0

3.4 Germany: An atmospheric office

You are running a big engineers company, specialising in water and waste technology. Needing more space, what do you do? You build a new, environmentally exemplary office building. At least, that is what Wasser- und Abfalltechnik lngenieurgesellschaft GmbH, (Water and Waste Technology Engineers Ltd.) in the German town of Karlsruhe did. Light and fresh air play a major role in the prize-winning office building.

Picture1 - South west elevation of the facade. South facade with light shelves and air collectors.

Rule number one in advertising: the inside must match the outside. A company proclaiming one thing yet working according to the opposite, will soon loose all credibility. No wonder, when WAT wanted to concentrate its activities in one place, it was clear that its core business on energy, resources and waste recycling must receive appropriate expression in the new headquarters.
The idea was to create a building that breathes space and fresh air, aesthetically as well as in a literary sense. That way, WAT reasoned, the office would help build a dignified reputation for the company. Furthermore, an office like that would fit nicely into the surrounding new industrial building district.

As a guiding principle, the building should not only incorporate energy saving and environmentally sound characteristics, but for image reasons many of these should also be visible to the layman and the professional crossing the threshold. One strategic choice was for the multiple use of materials and design in order to perform several functions at a time (e.g. natural ventilation and no mechanical cooling) as cheaply as possible. The budget for specific costs was limited to approximately 1,000 US dollars/m^2.

Time consuming teamwork
Not all conditions were favourable. For instance very close to the south side of the building another office of the same height was planned. That made optimal use of daylight very difficult.
In the designing partnership, as usual for such projects, all engineers worked under the architect as subcontractors. The architect was responsible for the concept and co-ordination of the design and construction process. The wealth of innovative parts required close scrutiny by the design team, demanding time consuming work without extra financial profit.
The partnership was not always a flawless one. In some cases the debate even had personal consequences. But over numerous working sessions every step was repeatedly simulated, checked, corrected, rejected or rethought. The aim was always to achieve the optimum and not merely the smallest common denominator. The only concepts considered worthwhile were those that prevented loss of standards, minimised energy consumption, used recyclable and/or recycled materials and yet could stay within market price range.

Solar air collectors
Since January 1995, the WAT headquarters is occupied and is functioning very well. It consists of a basement, three upper working floors and an attic. The most remarkable element of it is the cleverly combined heating and ventilation system, leading to very low energy consumption, well within budget range.
First there are the facade-integrated solar air collectors in the parapets on the south facade. Those collectors heat up incoming external air, sucked inside by fans in each level's floor. The facade's function thus has become a double one of protective skin and thermal source.
The solar preheated air is pressed by a fan through air ducts placed in the concrete floor. The floor acts as storage of heat and at the same time conducts the preheated air to openings where it is blown into the work spaces. No suspended 'lowered' concrete ceilings with air ducts inside were applied, but normal concrete ceilings do buffer the energy. Convectors for heating are located close to the facade. In summer a bypass flap allows to use the ducts for a night cooling of the ceilings.

Solar chimney
Rising air flowing towards the central east-west axis of the building encounters a heavy wall. By means of thermal mass that wall acts as a buffer for the southern part of the building with its high thermal load. Moreover a second special feature of the building: a 'solar chimney' is built into the wall. During daytime the chimney wall - glazed to the upper atrium - is heated by the solar radiation. The collected heat drives the night ventilation by the chimney effect, sucking cold outside air through the south facade and cross through offices and combined space. The upper part of the chimney draws warm exhaust air upward, out of the building for ventilation. For the day in summertime the air (precooled by water surfaces at the north side) is let in at the bottom of the chimney. At the same time the chimney is a passive solar device, recovering exhaust air heat for heating up fresh air to be used in the spaces on the north side.

Light shelves
For the daylight and shading system originally four alternatives were considered. Fixed outside prism lamellas, inside prism louvers, moveable outside prism lamellas and finally 'light shelves' underneath the upper windows. Being cheaper and effective, the light shelves were chosen.
On the outside, fixed horizontal flaps keep out any excess daylight in the summer months. Inside, moveable flaps can be tilted upward for closing in summertime. In bad lighting conditions they can be let down to a more horizontal position in order to reflect incoming light to the ceiling of the work

spaces. External horizontal lamellas for the windows and the facade integrated collectors can be controlled individually. So can the fans, windows, internal light shelves and external blinds. But normally air flow rate, shading and therefore temperature are bus system computer controlled. A daylight switch turns off the artificial lighting at a preset level of daylight, which can be overruled by the individual with an infrared portable switch.

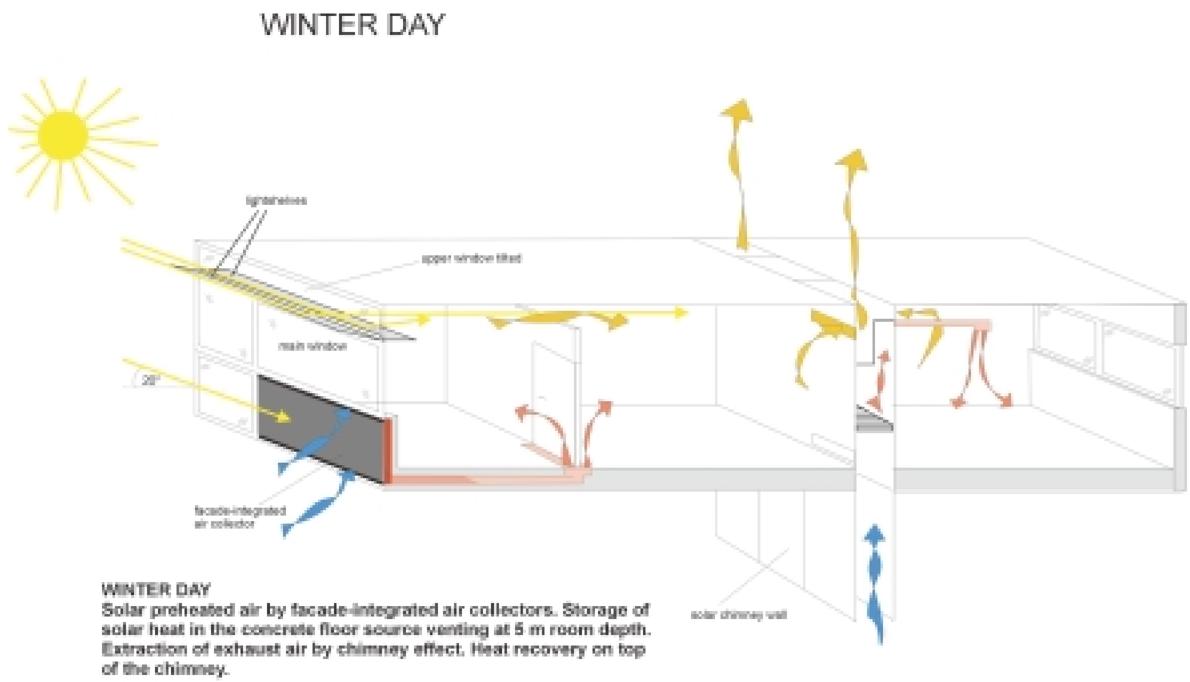
Well within budget

Other environmentally interesting features include: 9 m^2 of solar vacuum tube collectors for heating tapwater, a photovoltaically operated indoor fountain, retention of rainwater in a 214 m^3 storage cistern for flushing toilets, and daylight dependent switching off of artificial lighting.
Materials used are either recycled or recyclable. Nowadays in Germany that is a standard for many materials, but that was not yet the case in 1995.
Sometimes costs had to be cut. One flap in every air duct between solar wall and office room was rejected to save 10.000 US Dollars. Thus the natural ventilation is now more liable to malfunction. But all in all, the building runs very well, even though initially the users had problems understanding how the energy saving technology works and is to be operated. The specific costs stayed well within budget limits and would even, in comparable standard buildings, have been considered below average. The extra trouble the designers went through paid off in yet another way. The WAT - building earned the 'Umweltpreis der Stadt Karlsruhe' (Karlsruhe Environmental Award) and an award in the 'Baltasar Neumann Preis', one of the well known German architect prizes.

Resources used
1) TRNSYS
2) ADELINE
3) Scale models
In the design stage TRNSYS (a transient system simulation program) was used for thermal simulation because it both allows to specify system components and to perform a thermal building simulation.
For daylight simulations ADELINE was used, partly because it has an interface to TRNSYS.
An architectural model (scale 1:20) was used for control.

Lessons learned
- Innovative design and construction require an extra effort on the part of even a very experienced design and construction team. Conflicts may result.
- One should aim for optimum result, not just for the smallest common denominator.

Picture 2 - Ventilation strategy on a winter day.



USA: Student performance improved by daylighting

Durant Road School, Wake County, North Carolina, USA	New school building
Architect	Innovative Design, Raleigh, North Carolina
Engineers (HVAC/Energy/Comfort)	The Wooten Company
Latitude	36° North
Climate type	Mild
Heating degree days	1920 (base is 18.3°C)
Cooling degree days	787 (base is 18.3°C)
Building costs	1,150 US dollars /m^2
Total floor area	13,800 m^2
Heated surface	11,730 m^2
Insulation	U-value [W/m^2K]:
Walls	0.35
Roof	0.13
Windows	1.77
Total solar energy transmission	56% (estimate)
Annual energy consumption	130 kWh/m^2
Applied technologies	Extensive daylighting, south and north facing roof monitors, mechanical ventilation with heat recovery
Further information	NREL J. Douglas Balcomb 1617 Cole Blvd. Golden, CO 80401 USA Phone: +1 303 384 7507

3.5 USA: Student performance improved by daylighting

Persistence can overcome even strong outside reluctance, if objectives of cost-effectiveness are met, that is. A case in proof is Durant Road School in Wake County, North Carolina, USA. Daylighting the teaching environment brought down the energy consumption by some 50 percent, thus leading to a recapturing of additional cost within two years. What's more, recent studies brought to light a 5 to 21% enhancement of pupils' test scores in daylit schools. A solar boost for teaching.

On the face of it, Durant Road School would almost seem your average building. One storey throughout, laid out in heavy brick and concrete walls, dividing the building into 58 normal modular classrooms. A student and teaching population of about 320. Nice but unspectacular insulation indicators for walls, roof and double low-energy windows: what is so special about this building? Don't be deceived, the designers would say: considering the circumstances, Durant Road School is a shining example of innovation. Even CNN and the federal government have praised the project for outstanding results.

Saving energy costs

Indeed, at the outset conditions were far from perfect. Education in North Carolina is undergoing severe budgetary cutbacks, forcing responsible County School Boards to tighten their purse strings. Generally speaking, experimentation is frowned upon. Therefore, proposals, within the Wake County School Board, to build a school that would be mostly daylit, instead of being dependent on the usual artificial lighting, were met with traditional scepticism.

Early in the nineties, the opportunity to save energy costs was the main motivating factor which convinced the Board to allow an architect some freedom to pursue an innovative daylighting and energy conservation strategy in building the new middle school for pupils from 13 to 15 years of age. For the architect, Durant Road Middle School was not the first daylighting assignment. The Four Oaks Elementary School in the neighbouring Johnson County, which is similarly 'daylit', was an encouragement to the Board. Four Oaks had turned out to be quite a success, the energy cost dropping and the academic results going up simultaneously, without an increase in construction cost.

Nevertheless, before the architects began designing the building, the County established a detailed set of program guidelines, that all new construction must follow. Among others the guidelines included specifications of facility space, equipment and service requirements.
Additionally the School Board selected an engineering firm to work with the architect and watch over any questionable design proposals. The engineers were to make sure that the project stayed within the 14 million dollar budget, that deadlines were met and that all strict State and County regulations were followed.

Collaboration

The engineers and the architects had never worked together before. At times the relationship was an uneasy one, as the architects pushed for innovative features, while the engineers stuck to their more conservative role. Yet the net result was a successful collaborative effort, that may not have gone as far as the architects had initially envisioned, but went far beyond the standard solutions in the State's school building field.

The distinctive feature of Durant Road School is the use of buffered daylight instead of artificial lighting throughout the building. Moreover, heat is recovered from the mechanical ventilation system.
As yet, no final evaluation is available. But the predicted overall performance (based on computer models coupled with experience in other schools) is an energy consumption of 130 kWh/m^2. A typical school in North Carolina would have a consumption of more than twice as much.

Resources used

1) Physical Daylight Models
2) DAYLIT simulation programme (nowadays DOE - 2 E for energy simulations is the alternative)
3) TRACE: HVAC system computer program

These tools were used as a help in the design process and to demonstrate to the School Board the energy and lighting performance of the proposed design. The HVAC simulations, combined with the results of the daylighting simulations, were instrumental in deciding to reduce the size of the equipment.

Daylighting

Whereas flat roofs are the norm in North Carolina schools, in this case the designers used the roof to daylight the rooms. The most significant design feature is the system of tilted north and south facing roof monitors. Every major occupied space has natural light, including the gymnasium and cafeteria in the heart of the premises.
The three double-loaded classroom corridors are oriented along the east-west axis, thus allowing for maximum influx of daylight through the roof monitors above each classroom. The southward classrooms have south facing monitors. The monitors above the classrooms across the corridor have a northward slope. The result is an appealing impression of a typical 'old style' gable roof.

To prevent direct-beam sunlight in the occupied spaces, a set of translucent cloth vertical 'baffles' was fitted underneath every monitor. Through these baffles, incoming light from above is diffusely reflected and filtered downward onto the work floor area.
Interior courtyards too are fitted with a monitor and baffle system in order to provide natural light into the administrative area. Furthermore, every room has a daylight and occupancy sensor, controlling the three fluorescent lamp luminaries. Stepped switching turns on and off, either one, two or all three of them.

Other measures

Aside from providing a pleasantly lit working environment, the east-west orientation of the classroom corridors also maximises potential passive solar gain in winter - albeit that the south facing monitors perform much better than the north facing ones.
Together the solar gain, the heat recovery system, internal load, a well insulated envelope and low-e double glazing have almost eliminated the need for auxiliary heating.

A very strict State ventilation demand for schools (7 litres/sec/student) led the designers to install an air to air heat recovery system and the use of four-pipe heating and cooling with Variable Air Volume zone control. In this case heat pumps would not have been able to meet the high internal load resulting from the required ventilation rate.
The installed HVAC system (downsized considerably for the various achieved load reductions) allows teachers a strongly requested individual room control.

Picture 1 - A view inside the cafeteria at lunchtime when it is alive with students.

A highlight
Despite the daylighting and energy conservation measures the total construction cost was 12 million dollars, well below the 14 million dollar budget. This was achieved partly due to reducing the size of the HVAC systems (over the objection of the engineer). Nonetheless, the system has proved to be adequate and maintains good comfort.
The relationship between the School Board and the designers, as well as being supported by the steadfast leadership of the superintendent of the school system, was supported by two facts. Most importantly, the bid as a whole came within the budget. Secondly, early in the design stage scale models of the classroom roof monitor system were meticulously tested. Successful simulations were carried out under the North Carolina State University sky test facility. Also the architect used a HVAC simulation of the mechanical system, as well as an adapted version of the Daylit computer simulation program to determine the contribution of roof monitors to lighting conditions in the rooms. The simulation was instrumental in the decision to downsize the HVAC equipment, thus saving about half the added costs of the daylighting system.

Wake County's Durant Road Middle School was completed in 1995 and quickly received the spotlight of the media. The school was featured by CNN in a world wide television report, showing the enthusiasm of the teachers and the students' improved test scores. U.S. Secretary of Energy Hazel O'Leary paid a visit to the school and at the opening ceremony some (previously very sceptical) members of the School Board expressed their delight with the final product.

Lessons learned
- Persistence on the part of the architect can result in success.
- Careful design of a daylighting system saves energy, realises an agreeable working climate and leads to improved student performance.

By far the most significant result of the Durant School, and three other daylit schools designed by Innovative Design, is the documented performance improvement of the students resulting from the daylighting. Test scores, compiled over a 5-year period, reveal improvements of 5 % to 21 %, compared to state-wide averages. Subsequent evaluations in three other US states (involving 20,000 students altogether) confirm similar test score improvements.

Picture 2 - A typical roof monitor seen from below. This shows the hanging baffles that diffuse the light, creating a more uniform distribution of light and eliminating all beam sunlight that would otherwise cause glare.

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

The International Energy Agency (IEA) was established in 1974 as an autonomous agency within the framework of the Economic Co-operation and Development (OECD) to carry out a comprehensive program of energy co-operation among its 25 member countries and the Commission of the European Communities.

An important part of the Agency's program involves collaboration in the research, development and demonstration of new energy technologies to reduce excessive reliance on import oil, increase long-term energy security and reduce greenhouse gas emissions. The IEA's R&D activities are headed by the Commitee on Energy Research and Technology (CERT) and supported by a small Secretariat staff, headquartered in Paris. In addition, three Working Parties are charged with monitoring the various collaborative energy agreements, identifying new areas for co-operation and advising the CERT on policy matters.

Collaborative programs in the various energy technology areas are conducted under Implementing Agreements, which are signed by contracting parties (government agencies or entities designated by them). There are currently 40 Implementing Agreements covering fossil fuel technologies, renewable energy technologies, efficient energy end-use technologies, nuclear fusion science and technology, and energy technology information centres.

The Solar Heating and Cooling Programme was one of the first IEA Implementing Agreements to be established. Since 1977, its 20 members have been collaborating to advance active solar, passive solar and photovoltaic technologies and their application in buildings.

Australia	Finland	Norway
Austria	France	Spain
Belgium	Italy	Sweden
Canada	Japan	Switzerland
Denmark	Mexico	United Kingdom
European Commission	Netherlands	United States
Germany	New Zealand	

A total of 26 Tasks have been initiated, 19 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition, a number of special ad hoc activities - working groups, conferences and workshops - have been organised.

The Tasks of the IEA Solar Heating and Cooling Programme, both completed and current, are as follows:

Completed Tasks:

Task 1	Investigation of the Performance of Solar Heating and Cooling Systems
Task 2	Co-ordination of Solar Heating and Cooling R&D
Task 3	Performance Testing of Solar Collectors
Task 4	Development of an Insulation Handbook and Instrument Package
Task 5	Use of Existing Meteorological Information for Solar Energy Application
Task 6	Performance of Solar Systems Using Evacuated Collectors
Task 7	Central Solar Heating Plants with Seasonal Storage
Task 8	Passive and Hybrid Solar Low Energy Buildings
Task 9	Solar Radiation and Pyranometry Studies
Task 10	Solar Materials R&D
Task 11	Passive and Hybrid Solar Commercial Buildings
Task 12	Building Energy Analysis and Design Tools for Solar Applications
Task 13	Advanced Solar Low Energy Buildings
Task 14	Advanced Active Solar Energy Systems
Task 16	Photovoltaics in Buildings
Task 17	Measuring and Modelling Spectral Radiation
Task 18	Advanced Glazing and Associated Materials for Solar and Building Applications
Task 19	Solar Air Systems
Task 20	Solar Energy in Building Renovation

Completed Working Groups:

CSHPSS
ISOLDE
Materials in Solar Thermal Collectors

Current Tasks:

Task 21	Daylight in Buildings
Task 22	Building Energy Analysis Tools
Task 23	Optimization of Solar Energy Use in Large Buildings
Task 24	Solar Procurement
Task 25	Solar Assisted Air Conditioning of Buildings
Task 26	Solar Combisystems
Task 27	Performance of Solar Facade Components
Task 28	Solar Sustainable Housing
Task 29	Solar Crop Drying
Task 30	Solar City (Task Definition Phase)

Current Working Groups:

Evaluation of Task 13 Houses
PV/Thermal Systems (Definition Phase)

To receive a publications catalogue or learn more about the IEA Solar Heating and Cooling Programme visit our Internet site at http://www.iea-shc.org or contact the SHC Executive Secretary, Pamela Murphy, Morse Associates Inc., 1808 Corcoran Street, NW, Washington, DC 20009, USA, Tel: +1/202/483-2393, Fax: +1/202/265-2248, E-mail: pmurphy@MorseAssociatesInc.com.

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme