Integral Planning of Commercial Buildings

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The technical trades in building construction, in particular air conditioning, do not have a good image in Germany. Since the global energy crisis in the beginning of the seventies, in the public eye technical building services are the second-highest energy consumer after cars. Nearly all industrial countries have taken measures against waste of energy, above all in order to protect primary energy resources. This seemed to be more important from an economical point of view regarding availability and exhaustibility of these limited resources as their prices did not increase in a way that self-regulation could have been achieved over the market or price.

In the last decade, to the fear of exhaustibility of primary energy resources came up the fear of destroying the environment. In the Convention of Montreal high aims were set demanding from us plenty of force, money and willingness for change.

In spite of legislation enforced in Germany for economizing energy as for example the regulations for

- Insulation against Loss of Heat, the so called „Wärmeschutzverordnung"
- HVAC systems, the so called „Anlagenverordnung"
- Heating Accounting, the so called „Heizkostenabrechnungsverordnung"

buildings still consume too much energy.

Buildings need about 40 %
of the primary energy consumed in total
within our national economy.

Minimizing of energy consumption
is necessary for both ecological and
economical reasons.

Further on the focus of this paper will be set more on the economical than on the ecological aspects. In Germany legislation covers ecology sufficiently, but not always obviously or well balanced, i.e the 1995 regulations for insulation against loss of heat to which will be reverted lateron.

First of all a building is an economical product. On the one side, it has to fulfill the user's requirements; as far as comfort is concerned, HVAC systems can influence limiting values like temperature, humidity, light, acoustics, concentration of pollutants, etc. On the other hand, the building has to meet aesthetic requirements; that is a pleasant design, a harmonic and nice facade, etc.

However, a building has also to fulfill an economical purpose. The relation of price/performance or price/exploitation has to be well balanced, like with any other economical product. This means the total costs, which are the investment costs **and** the operating costs must be recoverable via the rent within the total time of exploitation. These operating costs, which may be considered as a kind of **Second Rent**, play an ever increasing part.

The economical and also ecological target can be reached by Integral Planning, meaning simultaneous collaboration of all parties involved in a construction project, right from the beginning on, when the preliminary design is made. Planning of the entire entity or Integral Planning has to replace the former way of planning, respectively the way still in use nowadays, in order to achieve optimization.

The usual planning procedure was characterized by the architect preparing his design, irreversibly and often under purely aesthetic aspects. Then it was the HVAC engineer's task to make the building habitable or exploitable, as the building was uncomplete from a constructional-physical point of view. Often, this was only possible by choosing enormously energy-consuming systems.

But also in the more restricted scope of technical building services, design and construction „as an entity" left and still leaves a lot to be desired. Technology has got more and more diversified with ever increasing speed especially during the last two decades, so that (large) buildings have become extremely complex technical systems involving numerous technical subsystems. However, the individual HVAC systems are linked together so tightly that separate evaluation or even seperate design does not make sense, especially seen from an overall view on energy consumption, because adding up various optima does not automatically result in a total optimum. The following example will demonstrate this.

Nowadays, in many buildings it is considered state-of-the-art to enlarge the emergency power unit of a building to a cogeneration plant. The exhaust heat of the cogeneration plant is fed into the heating assembly consisting of boiler and heat recovery machines, working mostly on storage. This will influence the operation and design of the heating assembly. The generated electrical power may be used to operate a ventilation system, for example. So this would affect the electrical and ventilation trades. It is a sensible economical and ecological way to use a cogeneration plant's heat for producing chilled water through the absorption refrigeration machines. This again requires coordinating the chilled water storage tanks and the chilled water users, etc. Finally, these interlinked systems must be coordinated to a sensible and economical entity by the interdsiciplinary technology of measurement & controls.

Though this shows that with increasing complexity of the trades, the importance of coordinating the interfaces and crossover points is ever increasing, nevertheless, design work were given out to a series of planners in the past. Not only HVAC systems have to be considered together in order to achieve energetical optimization, but also a building and ist HVAC systems influence each other in their complexe interaction. Only if a building and its HVAC systems are designed jointly by a team in an integral way right from the beginning, an optimal design solution will be achieved from an energetical point of view.

Integral Planning means
simultaneous design work performed by
architects, civil engineers and engineers
specialized in technical building services
with the objectives:
to plan, to build and to operate
an energetically optimized building.

Energy consumption of a building and its HVAC systems is determined by several values (see Figure 1).

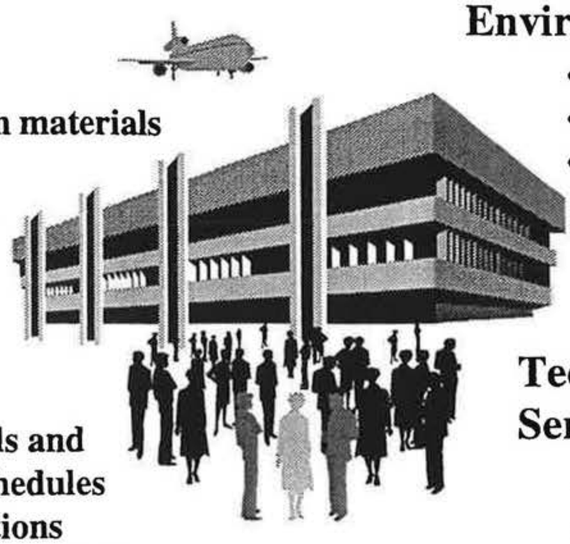


Figure 1: Influences on Energy Consumption of Buildings and Technical Building Services.

To summarize one may say:

A building can be considered to be optimized from the energetical point of view when the annual consumption of energy and other material resources required for Technical Building Services Plants or Systems are minimized in interaction with the overall building performance, while respecting all required criteria for acceptable comfort.

The target of designing an energetically optimized building can be achieved through Integral Planning by using the engineering tool **ROM Simulation Software**.

Simulation means imitating real physical processes. Mathematical formulation of these complex relations is performed and solved thanks to the fast development of high performance computers. The company **Rud. Otto Meyer** has made it its task to develop an overall, interacting system of simulation software, which we seek to improve constantly.

We offer this simulation tool to investors, owners of the properties, architects and engineers as a service with the aim to assist them to optimize the unit HVAC systems and building. It would be optimal if used right from the beginnig of the design process, already for the preliminary design. Figure 2 shows the structure of the tool.

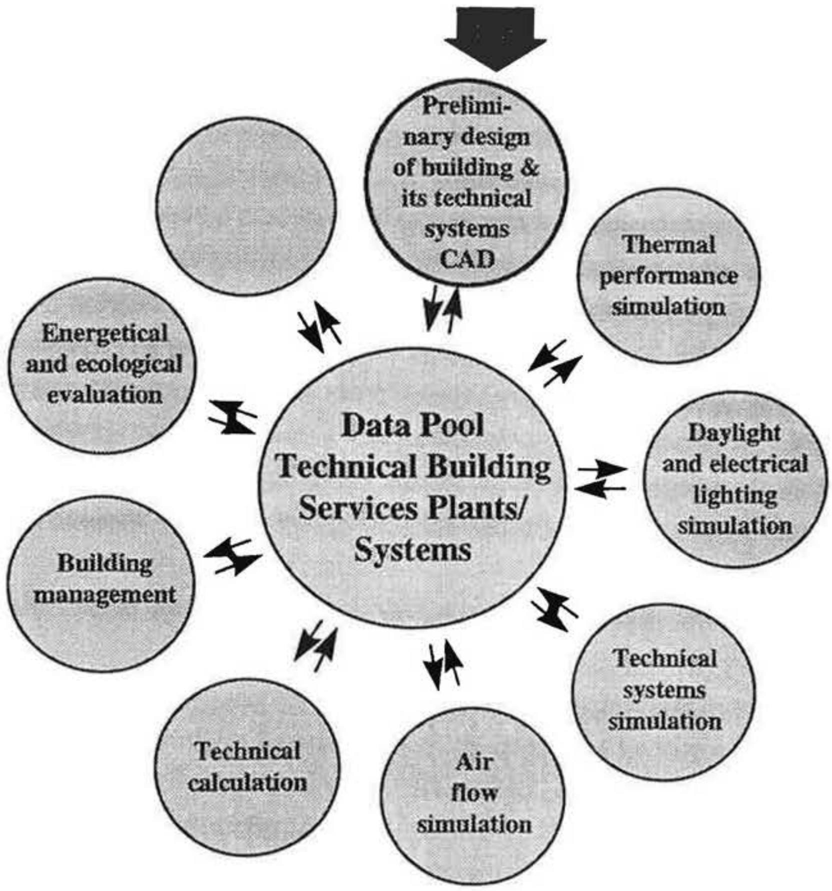


Figure 2: ROM Simulation Software.

The various simulation programs and other analysis software are linked to a data pool and they are supplementable and interchangeable. The preliminary design of a building and its HVAC systems is prepared by CAD. The geometry, constructional-physical and other relevant data are stored in the data pool. The different programs share information via the data pool. An interactive move forward or backward in the design process is therefore possible. The main programs of the simulation software will now be explained in detail.

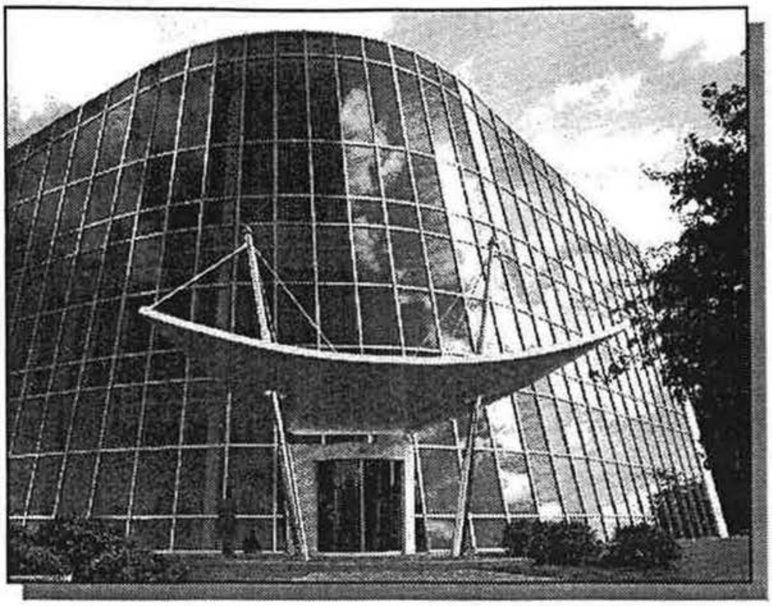
Thermal Performance Simulation

Thermal performance simulation computes all heat and material flows affecting a building and its internal zoning on the basis of constructional-physical laws. The essential inputs are:

- wall construction where insulation and heat storage capacity are of decisive influence,
- window qualities, such as size, kind of glass, shading,
- internal loads due to people, machines, lighting,
- external loads due to weather (temperature, solar radiation, wind),
- conditions of utilization: comfort and production-dependent limits.

The ambient conditions being created are of interest to thermal performance simulation. They show the climate within the building created by external and internal loads. The essentially interesting questions are:

- How is the course of the indoor temperature?
- How high is the exceeding of the limiting values?



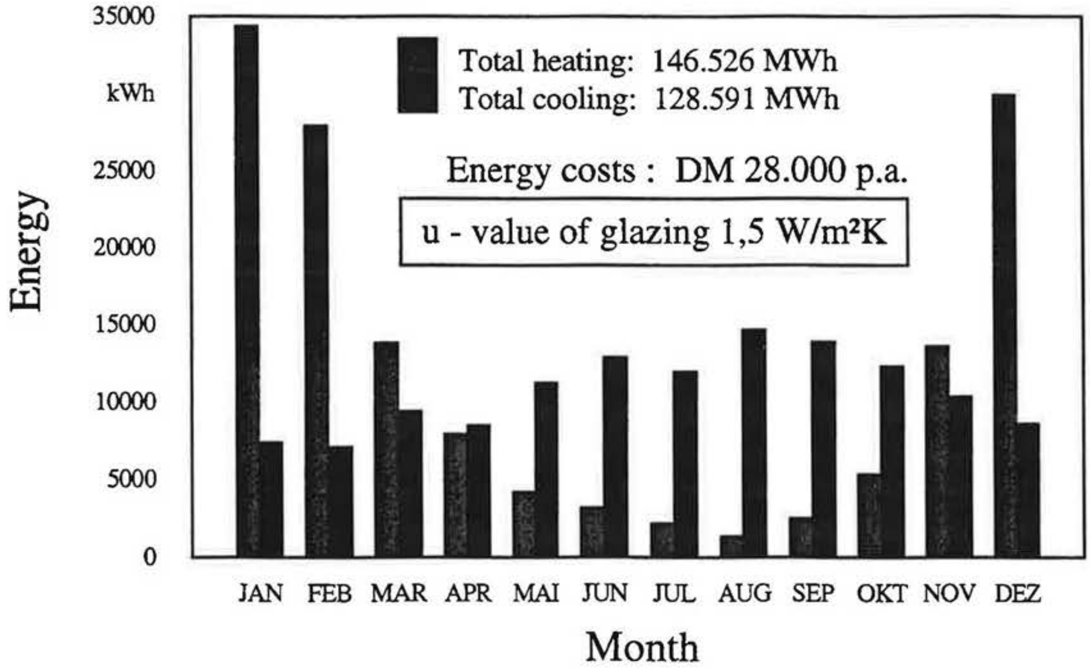


Figure 3: Energy Demand of an Office Building During a Year.

Glazing is shown with a lower heat transmission coefficient of 0.4 instead of 1.5 W/m^2 K, which means a better u-value. This reduces the heating energy demand by 30 % as expected, but the energy demand for cooling increases by 17 %. As the energy price for cooling is about double as high as for heating, the annual energy costs remain nearly unchanged (Figure 4).

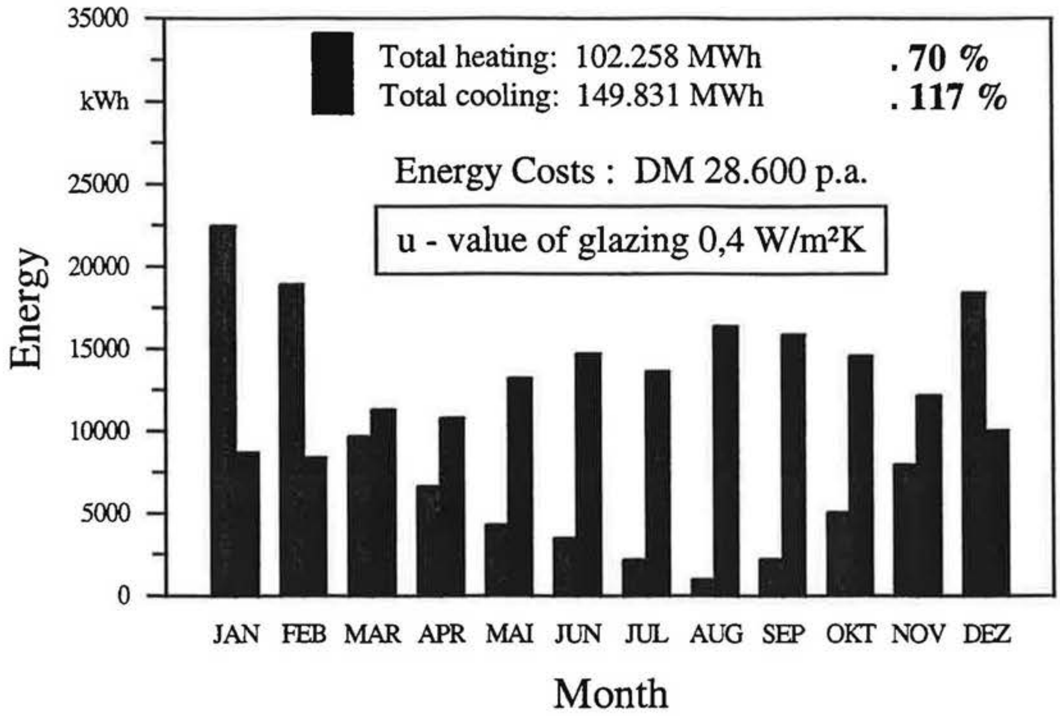


Figure 4: Energy Demand of an Office Building During a Year with new Glazing.

Photometric Simulation

It is tightly linked to Thermal Performance Simulation and they should be considered together. Figure 5 shows the result of a photometric simulation of a conference room with optimally distributed head lights in photorealistic presentation, with lines of equal intensity of lighting, so called ISOLUX lines.

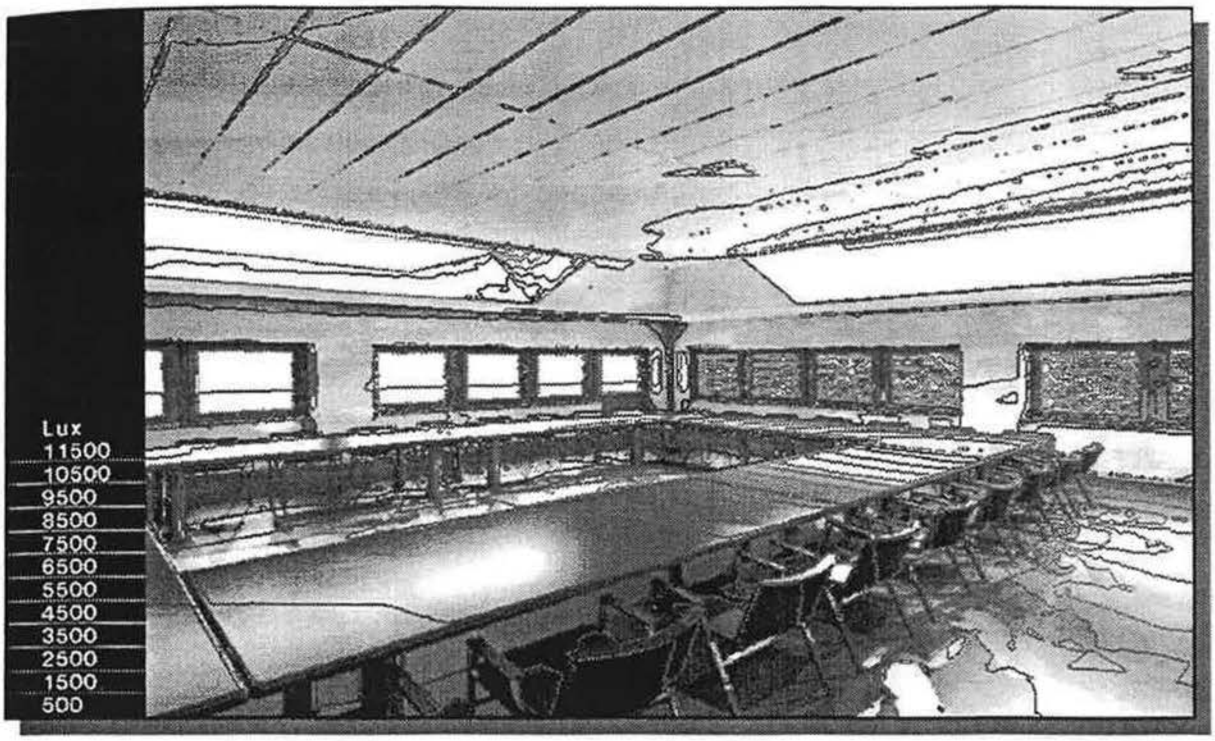


Figure 5: Result of a Photometric Simulation.

The larger the window surface, the higher is the possible utilization of daylight. However, in the same ratio increases the cooling load (greenhouse effect). If smaller window surfaces or additional shadings are chosen to compensate this in order to ensure a minimum brightness in the entire room depth, corresponding electrical lighting has to be used. This will increase the inside cooling load as the essential energy part of light production is heat.

The results of these reflexions, respectively these data are of decisive importance and must of course go into the Thermal Performance Simulation described before. This is a typical example how individual design decisions influence each other.

Air Conditioning System Simulation

Photometric and thermal performance simulation will determine which loads, i.e. heating, cooling and humidity, have to be eliminated in order to keep certain limiting values. The HVAC systems are chosen and dimensioned on the basis of these loads. They will be energetically assessed by simulation, down to their components and the control strategy.

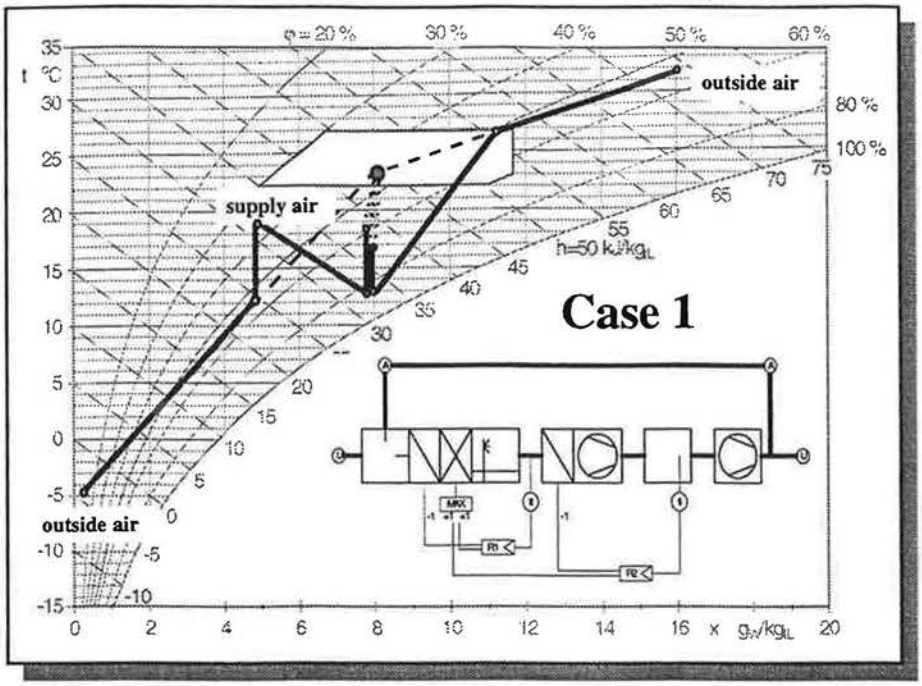
The two examples seen in Figure 6 show which influence system design and control strategy have on the systems energy consumption. Both cases have the same usual assembly of the air conditioning plant as far as mixing chamber, preheater, chiller, washer chamber, reheater, fresh air fan chamber and exhaust air fan are concerned.

Case 1 is controlled via the dew-point and a constant internal air condition is obtained. Case 2 is essentially of the same design, however, it has a controlled washer as well as a controlled mixing chamber and it works with variable air conditions within the scope of comfort.

The system from case 2 requires only

35 % of the heat
52 % of the cold
40 % of the water

compared to case 1 (Fig. 7).



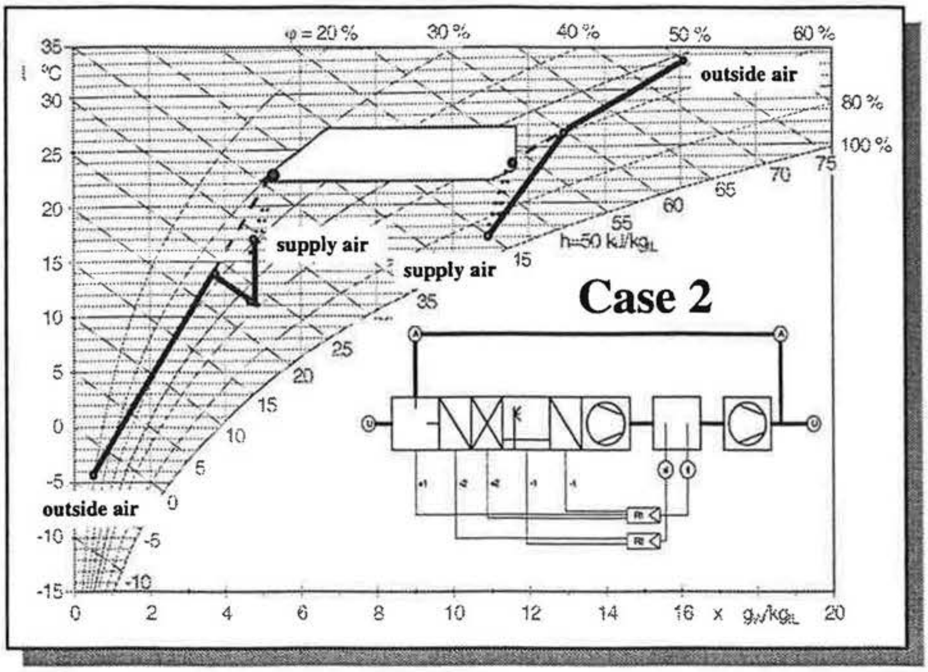


Figure 6: Air Conditioning System Simulation.

However, with this example, the work, that is the electricity consumption of the ventilator remains constant as nothing was changed. The annual operating costs of the total system are reduced to 74 % (Figure 7).

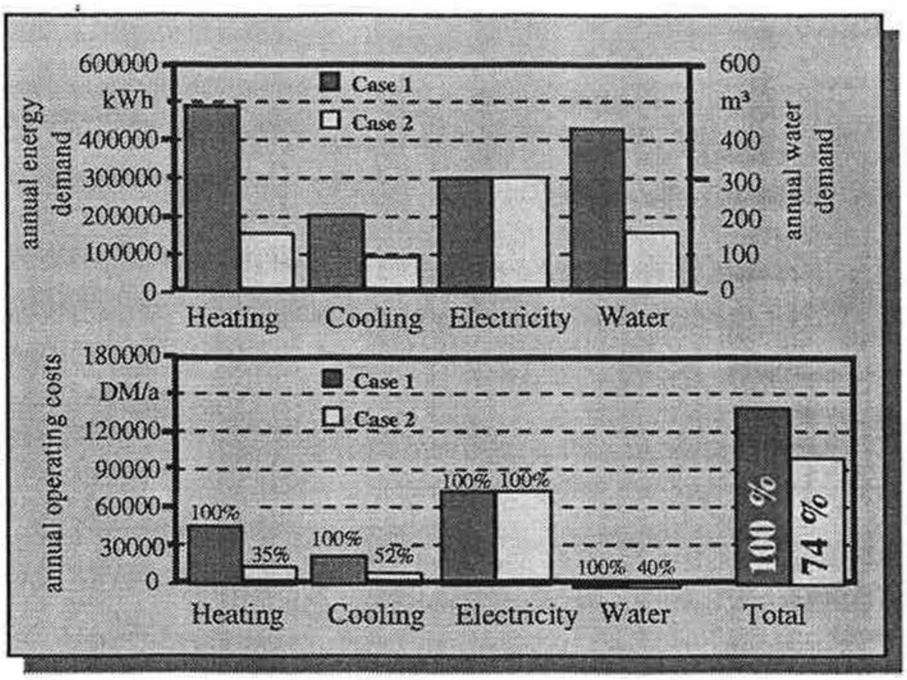


Figure 7: Result of the Air Conditioning System Simulation.

The process of optimized selection of system components and realizing optimal control strategy concerning

- energy consumption,
- operating costs or
- ecological relevant factors

has been developed by ROM and it is patented.

Air Flow Simulation

ROM uses air flow simulation in three areas to determine extensively and finally air flows and comfort in buildings as there are:

- flow around a building,
- flow through a building,
- fow inside the building.

The results which are aimed are:

- distribution of pressure formed by the wind flow around the building,
- air change rates,
- indoor air speeds,
- indoor temperature distribution,
- indoor pollutant concentration.

Further on the three applied areas of flow simulation shall be explained in detail.

1. External Air Flow Simulation

First, that is the first phase of Integral Planning the external flow around the building is examined, in particular distribution of pressure on the building envelope. Such tests used to be expensive and had to be carried out on building models in a wind tunnel. Nowadays, we use this simulation also to determine for instance exhaust gas spreading of a cogeneration plant in the vecinity of buildings with openable windows (see Figure 8).

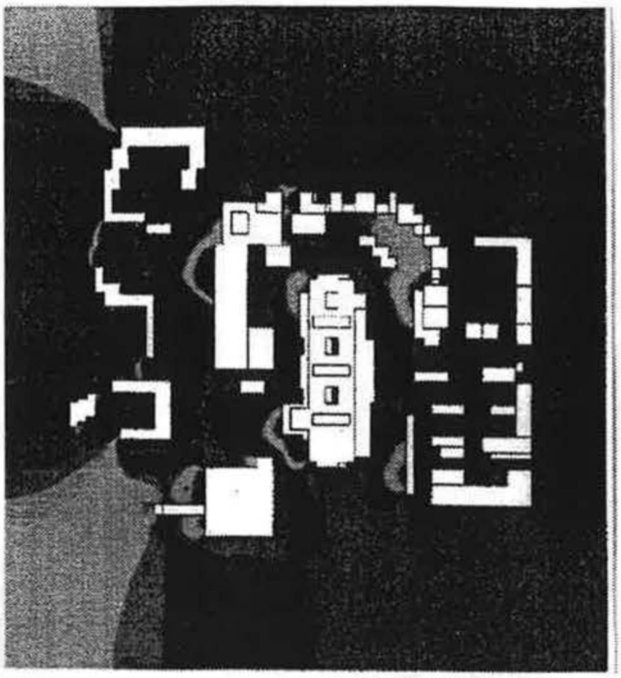


Figure 8: Simulation of External Air Flow.

2. External Air Infiltration

This simulation takes as base the external pressure distribution as described before and the indoor building zoning. Depending on the flow resistance, door and window cracks etc. one find out the infiltration through indoor zoning (Figure 9). The result is put into Thermal Performance Simulation.

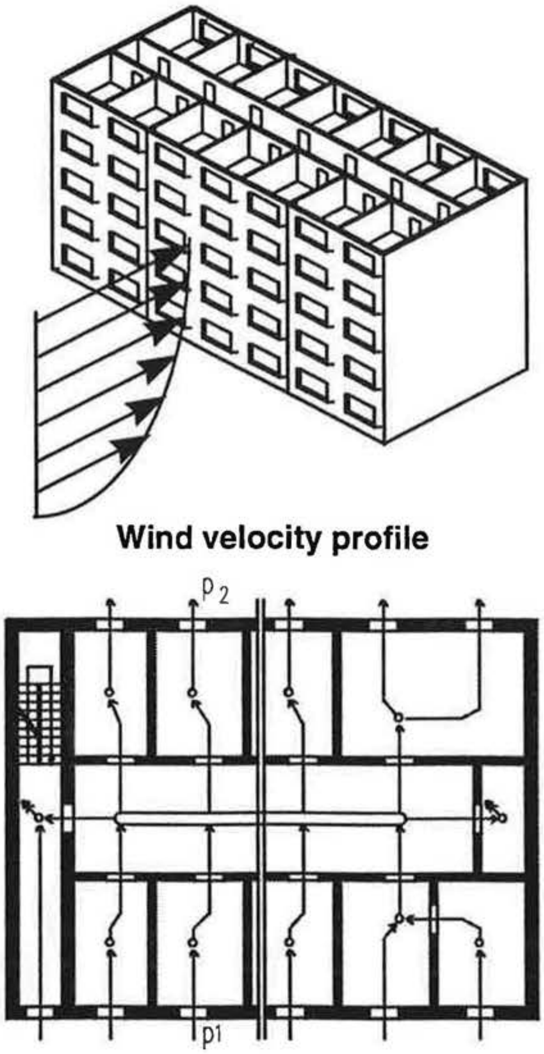


Figure 9: Simulation of External Air Infiltration.

3. Indoor Air Flow Simulation

Indoor Air Flow Simulation is used for evaluating room comfort. As results are obtained:

- Indoor air speed (vector representation),
- Indoor air temperature (colour representation, see Figure 10),
- Concentration of pollutants (CO_2, color representation).

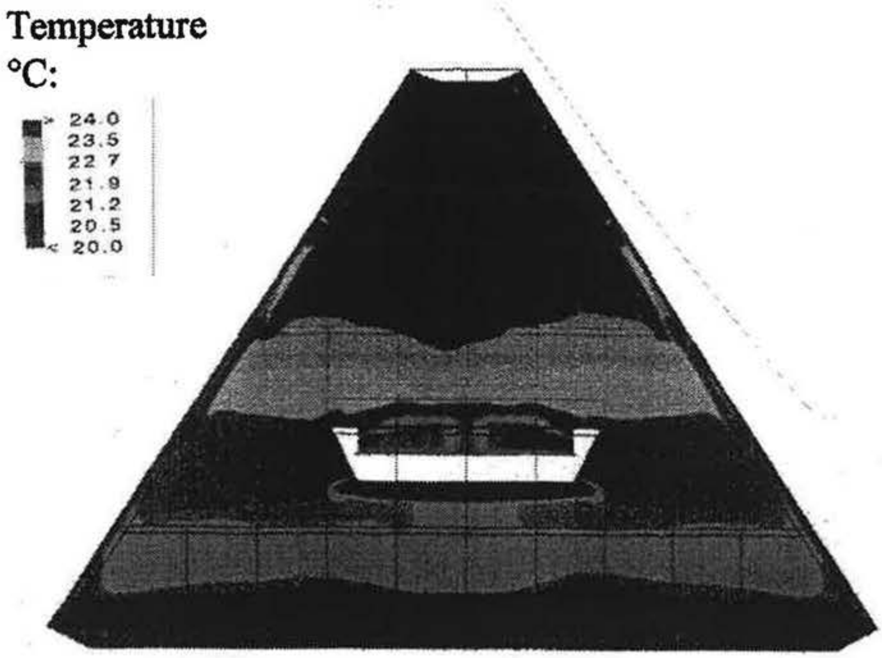


Figure 10: Temperature Distribution in a Glazed Entrance Hall.

Air Flow Simulation Laboratory

ROM, being a product-independent engineering company, has been operating an air flow simulation laboratory for over 40 years for the purpose of evaluating components and systems of different manufacturers. The results of flow-technical and thermo-dynamical tests have been documented and put into archives over years.

Laboratory trials have always been and still are expensive (model assembly, measuring techniques etc.). Sometimes simulation costs are about one tenth cheaper. If tests have to be made on a 1:1 scale, the laboratory is used, whereas flow simulation is generally more adequate to test complex buildings (for instance large glazed halls, atriums, etc.)

The successful development of ROM's Simulation Software is at least a product of laboratory trials which had also been computer-simulated, so that the software was rapidly and efficiently improved.

ROM looks back at 4 years of experience in Integral simulation-assisted Planning. We have tested, designed or optimized more than 50 building projects with our simulation tool. Naturally, all important data on the design and construction process are stored in a database. They are transferrable into our software for Building and Facility Management.

Finally, the key-word **Operating Costs** should be mentioned again which nowadays represent a **Second Rent**. These costs are coming ever closer into the focal point of interest of investors, construction owners, architects and ourselves, of course. To fix the contract price of a HVAC system or a complete building is not a problem for us in particular, neither for the construction companies in general. Contracts basing on all inclusive or maximum prices have been customary for years.

However, to fix the operating costs of a building, that is the **Second Rent**, is much more difficult. A multitude of crossover points in building construction, between building construction and technical building services trades, has made a realistic evaluation on the total operating costs impossible so far.

But as Integral Planning and construction progress further and by taking advantage of ROM's Simulation Software, we are sure that we shall soon be in a position to compute not only the investment costs of a building, including its HVAC systems, but also the operating costs, the essential part of the **Second Rent**, and guarantee these costs under certain contractual conditions.

However, to achieve contractual safety, there are still some problems to be solved:

- For instance, algorithms have to be developed to calculate operating costs for a real year on the basis of a test reference year (very cold winters / hot summers).
- User-specific influences must become controllable (window aeration, uncontrolled energy consumption, etc.)

These problems put aside, the Integral Planning, constructing and operating of a building and its HVAC systems should be the precondition to contract for the total-costs, which are investment and operating costs. This work could be performed by the skilled staff of a consortium, consisting of architects, consulting engineers, contractors as well as the building user in the sense of Building or Facility Management.

This way, design and layout would run simultanously from the beginning on, a working process the automobile industry adopted a long time ago. The designer and the production engineer must conceive the preliminary design and final layout in synthesis so that the design of a product and its economical production form an entity.