BESTFAÇADE

Best Practice for Double Skin Façades

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WP 1 Report "State of the Art"

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Introduction

Innovative façade concepts are today more relevant than ever. The demand for natural ventilation in commercial buildings is increasing due to growing environmental consciousness while at the same time energy consumption for buildings has to be reduced. An advanced façade should allow for a comfortable indoor climate, sound protection and good lighting, while minimising the demand for auxiliary energy input. Double skin façades (DSF) have become an important and increasing architectural element in office buildings over the last 15 years.

They can provide a thermal buffer zone, solar preheating of ventilation air, energy saving, sound, wind and pollutant protection with open windows, night cooling, protection of shading devices, space for energy gaining devices like PV cells and – which is often the main argument – aesthetics.

Motivation

Commercial and office buildings with integrated DSF can be very energy efficient buildings with all the good qualities listed above. However not all double skin façades built in the last years perform well. Far from it, in most cases large air conditioning systems have to compensate for summer overheating problems and the energy consumption badly exceeds the intended heating energy savings. Therefore the architectural trend has, in many cases, unnecessarily resulted in a step backwards regarding energy efficiency and the possible use of passive solar energy.

The BESTFAÇADE project will actively promote the concept of double skin façades both in the field of legislation and of construction thus increasing investor's confidence in operating performance, investment and maintenance costs.

Definition

"A double skin façade can be defined as a traditional single façade doubled inside or outside by a second, essentially glazed façade. Each of these two façades is commonly called a skin. A ventilated cavity - having a width which can range from several centimetres to several metres - is located between these two skins.
Automated equipment, such as shading devices, motorised openings or fans, are most often integrated into the façade. The main difference between a ventilated double façade and an airtight multiple glazing, whether or not integrating a shading device in the cavity separating the glazing, lies in the intentional and possibly controlled ventilation of the cavity of the double façade".[1]

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[1] Belgian Building Research Institute - BBRI: Ventilated double façades – Classification and illustration of façade concepts, Department of Building Physics, Indoor Climate and Building Services, 2004

"Essentially a pair of glass "skins" separated by an air corridor. The main layer of glass is usually insulating. The air space between the layers of glass acts as insulation against temperature extremes, winds, and sound. Sun-shading devices are often located between the two skins. All elements can be arranged differently into numbers of permutations and combinations of both solid and diaphanous membranes".[1]

"The Double Skin Façade is a system consisting of two glass skins placed in such a way that air flows in the intermediate cavity. The ventilation of the cavity can be natural, fan supported or mechanical. Apart from the type of the ventilation inside the cavity, the origin and destination of the air can differ depending mostly on climatic conditions, the use, the location, the occupational hours of the building and the HVAC strategy. The glass skins can be single or double glazing units with a distance from 20 cm up to 2 meters. Often, for protection and heat extraction reasons during the cooling period, solar shading devices are placed inside the cavity".[2]

Objectives of Bestfaçade

The state of the art of double skin façades in different countries and climatic regions will be evaluated and a coherent typology of double skin façades will be developed.

A centralised information system database containing details and performance data collected from a survey of double skin façades built in the European Union will be established.

An assessment method will be developed, which on the one hand can be integrated in the assessment methods of the EPBD (Energy Performance Building Directive) and on the other hand offers sufficient accuracy of the thermal behaviour and the energy performance of the system.

Benchmarks will be made available to allow users and operators to compare their energy consumption levels with others in the same group, set future targets and identify measures to reduce energy consumption.

Non-technological barriers will be identified, solutions to overcome them will be presented and the results will be incorporated in the dissemination strategy.

A design guide including best practice examples will be compiled, providing the target group with a common basic scientific, technical and economic knowledge on double skin façades.

[1] Harrison K. & Meyer-Boake T.: The Tectonics of the Environmental Skin, University of Waterloo, School of Architecture, 2003

[2] Harris Poirazis: Double Skin Façades for Office Buildings – Literature Review. Division of Energy and Building Design, Department of Construction and Architecture, Lund Institute of Technology, Lund University, Report EBD-R--04/3, 2004

First of all the results of the project will be delivered to the main target groups:
The Primary Target Group with architects and designers, consultants, façade and HVAC industry, Investors, general contractors, building industry, standardisation bodies and The Secondary Target Group with building owners, building users, authorities, knowledge providers (Universities, Research Centres).

At the same time the project results will be disseminated by different strategies, like website, CD-ROMs, workshops and presentation at conferences, e.g. Energy Performance and Indoor Climate in Buildings.

Tasks

The project is structured along eight main work packages (WPs). The aim of WP1 "State of the Art" was to collect information on double skin façades and double skin façade related issues like energy consumption, user acceptance, etc. It has been running over a period of 12 months. The following WPs are WP2 "Cutback of non-technological barriers", WP3 "Energy related benchmarks and certification method", WP4 "Simple calculation method", WP5 "Best practice guidelines", WP6 "Dissemination", WP 7 "Common dissemination activities". All of them get their basic information from WP1 according to their objectives.

The interaction of the WPs is shown in the following picture and ensures a strong commitment of all partners.

Work package		year	1				2				3			
		quarter	**1**	**2**	3	4	5	6	7	8	9	10	11	12
WP1	State of the Art		■	■	■	■								
WP2	Cut-back of non-technological barriers				■	■	■	■	■	■				
WP3	Benchmarks and certification method				■	■	■	■	■	■				
WP4	Simple calculation method				■	■	■	■	■	■				
WP5	Best practice guidelines								■	■	■	■		
WP6	Dissemination		■	■	■	■	■	■	■	■	■	■	■	■
WP7	Common Dissemination Activities		■	■	■	■	■	■	■	■	■	■	■	■
WP8	Management		■	■	■	■	■	■	■	■	■	■	■	■

1 History

The history of Double Skin Façades is described in several books, reports and articles. Saelens mentions that "in 1849, Jean-Baptiste Jobard, at that time director of the industrial Museum in Brussels, described an early version of a mechanically ventilated multiple skin façade. He mentions how in winter hot air should be circulated between two glazings, while in summer it should be cold air" [1].

Crespo[2] and Neubert[3] claim that, the first instance of a Double Skin Curtain Wall appears in 1903 in the Steiff Factory in Giengen / Brenz near Ulm, Germany. According to them, the priorities were to maximize day lighting while taking into account the cold weather and the strong winds of the region. The solution was a three storey structure with a ground floor for storage space and two upper floors used for work areas. The building was a success and two additions were built in 1904 and 1908 with the same Double Skin system, but using timber instead of steel in the structure for budget reasons. All buildings are still in use.

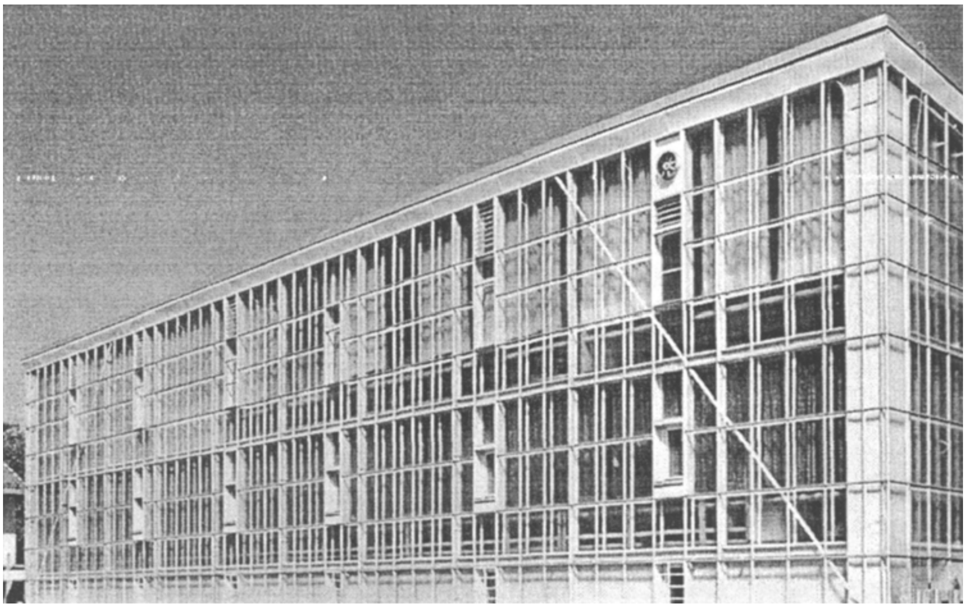

Fig. 1 Steiff Factory, Giengen / Brenz, Germany [Neubert]

[1] Saelens, Dirk: Energy performance assessment of single storey multiple-skin façades, Diss. KU Leuven, 2002

[2] Crespo, Ana Maria Leon: 3x2:Three takes on double skins", Harvard University, no date

[3] Neubert S.: Doppelfassaden – Ein Beitrag zur Nachhaltigkeit?, Ecole Polytechnique Federale de Lausanne, 1999

In 1903 Otto Wagner won the competition for the Post Office Savings Bank in Vienna / Austria. The building, built in two phases from 1904 to 1912 has a double skin skylight in the main hall. At the end of the 1920's double skins were being developed with other priorities in mind. Two cases can be clearly identified. In Russia, Moisei Ginzburg experimented with double skin stripes in the communal housing blocks of his Narkomfin building (1928). Le Corbusier was designing the Centrosoyus, also in Moscow. A year later he would start the design for the Cite de Refuge (1929) and the Immeuble Clarte (1930) in Paris and stated „la respiration exacte" („…an exactly regulated mechanical ventilation system…") and „le mur neutralisant" („...neutralising walls are made of glass or stone or both of them. They consist of two membranes which form a gap of a few centimetres. Through this gap which is enveloping the whole building in Moscow hot and in Dakar cold air is conducted. By that the inner surface maintains a constant temperature of 18° C. The building is tightened hermetically! In the future no dust will find its way into the rooms. No flies, no gnats will enter. And no noise!…") [1].

Little or no progress was made in double skin glass construction until the late 70's, early 80's of the past century. During the 80's this type of façades started gaining momentum. Most of these façades are designed using environmental concerns as an argument, like the offices of Leslie and Godwin. In other cases the aesthetic effect of the multiple layers of glass is the principal concern.
In the 90's two factors strongly influence the proliferation of double skin façades. The increasing environmental concerns start influencing architectural design both from a technical standpoint but also as a political influence that makes "green buildings" a good image for corporate architecture. [2]

[1] Le Corbusier: Feststellungen zu Architektur und Städtebau, Wiesbaden, 1964

[2] Harris Poirazis: Double Skin Façades for Office Buildings – Literature Review. Division of Energy and Building Design, Department of Construction and Architecture, Lund Institute of Technology, Lund University, Report EBD-R--04/3, 2004

2 Architectural Aspects of DSF in Europe

By WSP

2.1 The Conception of architecture

During a long period of time the European architecture was bound by a classical idiom descending from the ancient Greek art of building. The values were mainly esthetical where shape, proportions material and daylight were the main elements.

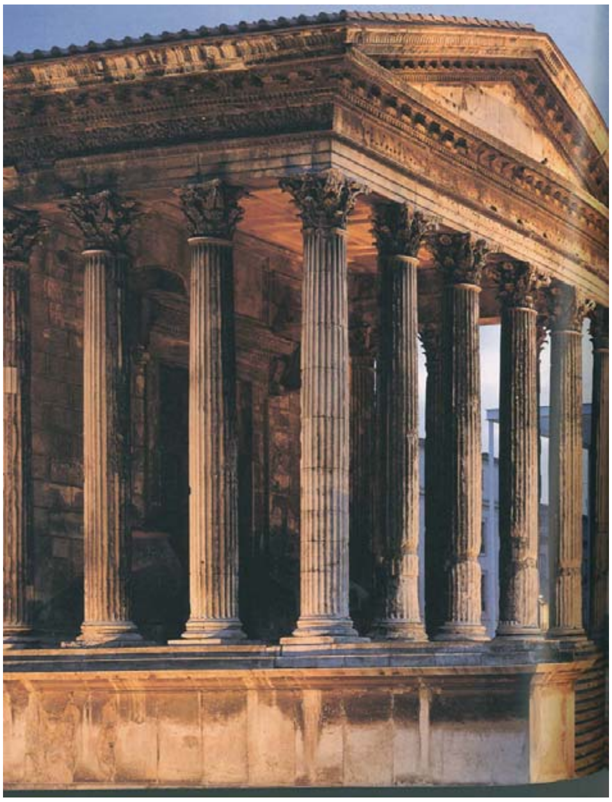

Fig. 2 Greek temple

During the later half of the 20th century global, climatic changes together with diminishing resources were evident signs that we must change our view on building and our way of living. Architecture is now a complex concept that applies to the appearance, the function, the technology of a building, as well as the approach to environmental issues and the influence on users and viewers.
Architectural aspects on the double glazed facade should rely on a complex evaluation of the whole of the building.

Fig. 3 A double glazed façade

2.2 Glass architecture

No other building material has during the last two decades experienced such an innovative increase as glass. It has evolved into a high-tech product that in its right use can create slender and bold constructions. In the beginning the increase of use was depending on the symbolic value of development and future. The complete transparency also showed a corporate will of communication and openness towards society outside. More recently the improved properties and its possibilities to participate in a complex construction increased the use of this type of facades. The double glazed façade becomes a part of the buildings technology and the concern of the owner/developer concerning ecology and energy is transferred visually to the outer shell of the building. The double glazed façade is no longer seen as an expensive cost but as a long-term investment.

Fig. 4 Section showing constructive elements through the façade

2.2.1 Collaboration

Double glazed facades becomes apart from an architectural expression also a part of the technological systems of the building. A demand on a holistic approach and collaboration between participators becomes more significant than in a traditional building system where the façade usually acts a passive part of the building. In an outer wall with two layers the façade becomes an active climatic screen, that can be used in the energy system of the building and improve the indoor climate, increase the use of daylight, solar shade and decrease noise in exposed areas. If the traditional façade gives the architect a freedom of expression, double-glazed facade and the design of its building demands collaboration with engineers and suppliers. This cooperation will affect the architecture in many ways.

2.2.2 Light

The natural daylight and its positive effects on humans have always been a main ingredient in architecture. The treatment of the light affects the experience of space and inner clock of humans: Alert and awake, tired and drowsy. Set design and well being. Shadows, reflection, dazzle, colour of light and distribution. Everything affects and should take part.

Surveys show that daylight has significant effect on performance as well as physical health. Humans living in the northern hemisphere are more likely to be affected by depressions than those living closer to the equator. To increase the amount of daylight is apart from its effects on humans an important environmental factor since it diminishes the use of electricity for light.

The double glazed façade has increased the interest for daylight issues. The large share of glass enables light to penetrate the building. A glazed building should be designed with a maximisation of light intake in mind, in order to minimize the dark parts in the core.
St Mary Ax in London is good example with its circular layout where pie slices has been cut out to bring light in to the building, avoiding darkness in the central core.

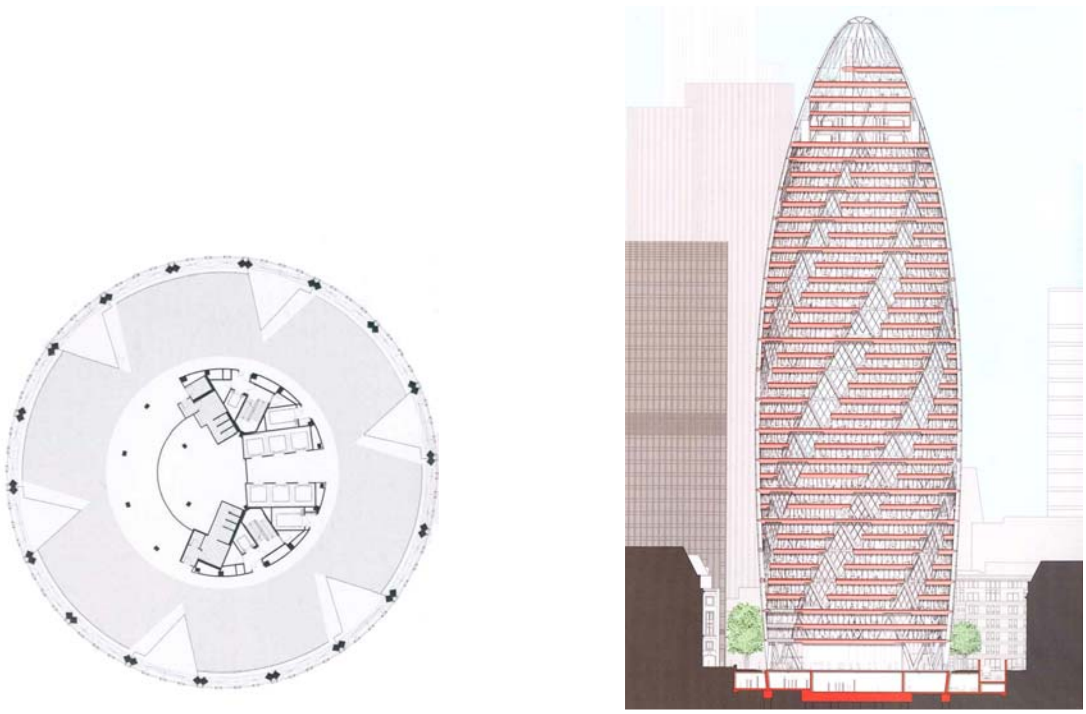

Fig. 5 St Mary Ax, plan + section

However, careful planning is necessary for a glazed facade with the amount of light that is allowed into the building. Dazzle may occur particularly when the sun is low. A solution can be lamellae with dual functions. One is to screen the sun and the other is to link the light further in to the building via the higher lamellae. In the night time the glazed building receives a third dimension and become lantern expressing comfort in the dark.

Fig. 6 DSF in the night

2.3 The multitude of the city

The City contains a large amount of buildings where the expression of the single building contributes to varied experience. There is the stone town with a grid and heavy facades in masonry or plaster, there are the monotonous residential areas in the periphery with its rational and similar buildings, there are large scale industrial or commercial complexes and there are areas with small scale single family housing. The history of the city growth can be read in the characters and the style of the different epochs. A glazed building is to be added to this collection and contributes to the multitude that is of great importance in the city structure, telling its story about time to come yet reflecting the old in the façade.

Fig. 7 Baltzar City, Malmoe

2.4 General Buildings

Increasing costs for buildings demands generality of the building. During an approximated life span of 100 years for a building it will shift tenants and interiors many times. In every change extensive reconstruction will be made, possibly leading to extensive and expensive interference. A whole-glazed façade may enable a generic layout with a high level of use as a consequence.

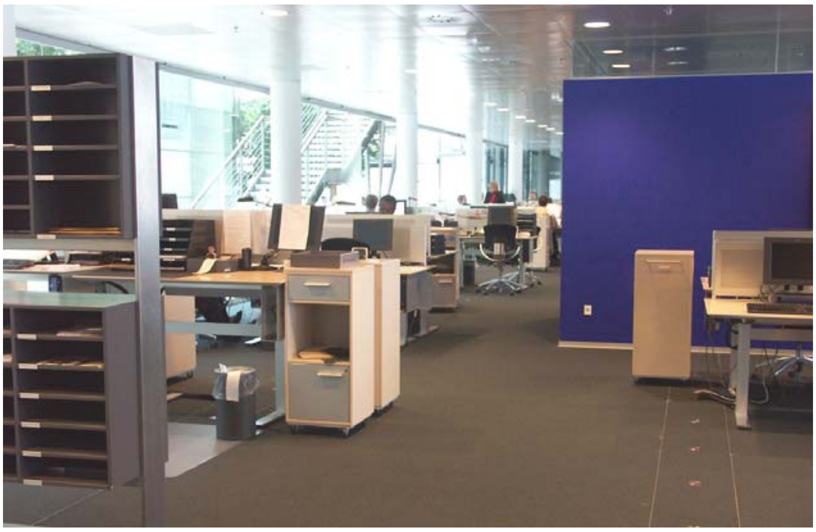

Fig. 8 Picture, interior

2.5 Environmental Architecture

Out of total energy consumption by a building, from erection to demolition 15 percent derives from the actual construction, while 80 percent is used for the operation. During the last decades the common attitude has changed concerning environmental and energy consumption, now a natural part of architecture. The double glazed façade claims to keep energy in mind and fits very well with this new way of thinking, however it is not always obvious to design the façade with a transparent shell.

Seen from the perspective of energy consumption there are no reasons to have identical facades facing different directions. Contrary the design can be based on the point of the compass the façade is facing. The south façade is suited for making use of solar heat. Solar panels and double-glazing where the interval is used ventilation, collection of heat and as protection for blinding functions. The façade facing north can have a more traditional expression with smaller windows and have higher level of insulation. The east and west facades may face overheating problems in summer due to lower incident angle and low passiv solar gains during winter. Therefor this orientations have to be treated very carefully. In this way the architecture becomes more environmentally adjusted depending on the location of the building. If the site allows large amount of facades facing east or west both these can be constructed as double layer glazing with a function in between.

2.5.1 The facade of communication

During the 21st century the increased use of glass has given birth to new kind of architecture, with facades communicating with its surroundings. In the water-saturated town of Stockholm, a new hotel is designed using glass façade with water sparkles, telling the story of the seabed transformed into the site.

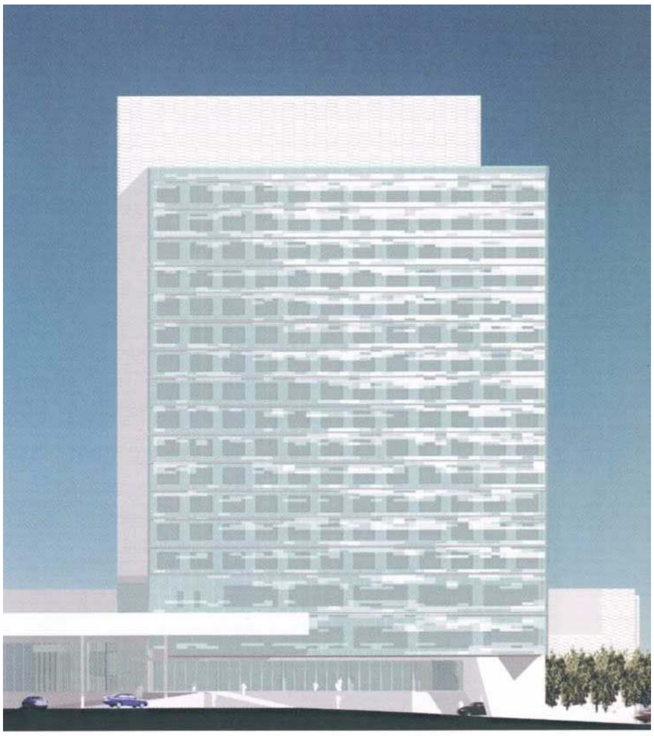

Fig. 9 Model of a façade with water sparkles

A double glazed façade can mediate something about the contents on the outer glass by moving- or still pictures. With cameras placed in the void producing chosen pictures expressing an animated exterior. The building can be used to express the corporate policy and the glass will act as a potential billboard.

2.5.2 The sound attenuating façade

The site concludes the orientation and shape of a building, as well as the choice of facades and technology. Attributes that efects the architecture, all sites are not suitable fore single- or double glazed facades, and all sites are not suited for a closed building typology. Close to a highway or a loud industry the double façade can act as a effective noise suppressor and create a comfortable indoor climate. Earlier the architect would choose a heavy façade with smaller windows, thereby creating a dim and dark interior. Now there is a choice of using the transparent façade with its views and daylight, yet protecting its inhabitants from the loud exterior.

2.6 Future

Utopian portraits almost always include transparent buildings of different kinds. Will the double glazed façade become the skin of buildings in the future? Glass can now be delivered with almost all the properties that are needed for a shell with an exception for efficient energy insulation. If glass architecture is to survive it must limit its influence on energy losses by new innovative solutions.

It is not probable that architects will rely entirely on glass buildings in the future. The site, demands and supply of material will still be decisive. A positive development for the glass as a material increases the possibility of making into a universal building material with more glass building as a consequence. Humans have since time immemorial searched for one material to build with. Multifunctional glass facades may be this building technique of the future. Gone are the masonry walls with its many layers in the solid parts with openings for light and communications. Architects, artists and engineers will stretch the borders searching for new expressions and vivid façade surfaces.

3 Technical description

3.1 Exterior and interior glazing

The choice of the glass type for the interior and exterior panes depends on the typology of the façade. In case of a façade ventilated with outdoor air, an insulating pane (= thermal break) is usually placed at the interior side and a single glazing at the exterior side. In case of a façade ventilated with indoor air, the insulating pane is usually placed at the exterior side, the single glazing at the interior side. For some specific types of façade, the interior window can be opened by the user to allow natural ventilation of the building.

3.2 The air cavity between the exterior and interior glazing

The ventilation of the cavity may be totally natural, fan supported (hybrid) or totally mechanical. The width of the cavity can vary as a function of the applied concept between 10 cm to more than 2 m. The width influences the physical properties of the façade and also the way that the façade is maintained.

3.3 The shading device

The shading device is placed inside the cavity for protective reasons. Often a venetian blind is used. The characteristics and position of the blind influence the physical behaviour of the cavity because the blind absorbs and reflects radiation energy. Thus, the selection of the shading device should be made after considering the proper combination between the pane type, the cavity geometry and the ventilation strategy and has a high impact on the daylight situation within the rooms behind.

3.4 Openings

Openings in the external and internal skin and sometimes ventilators allow the ventilation of the cavity.

The choice of the proper pane type and shading device is crucial for the function of the Double Skin Façade system. Different panes can influence the air temperature and thus the flow in case of a naturally ventilated cavity.

The geometry (mainly width and height of the cavity) and the properties of the blinds (absorbance, reflection and transmission) may also affect the type of air flow in the cavity. When designing a Double Skin Façade it is important to determine type, size and positioning of interior and exterior openings of the cavity since these parameters influence the type of air flow and the air velocity and thus the temperatures in the cavity (more important in high-rise buildings). The design of the interior and exterior openings is also crucial for the flow indoors and thus the ventilation rate and the thermal comfort of the occupants.

It is really important to understand the performance of the Double Skin Façade system by studying the physics of the cavity. The geometry of the façade, the choice of the glass panes and shading devices and the size and position of the interior and exterior openings determine the use of the Double Skin Façade and the HVAC strategy that has to be followed in order to succeed in improving the indoor environment and reducing the energy use. The individual façade design and the proper façade integration is the key to a high building performance

Potential advantages with office buildings with double skin facades can be (compared with traditional office buildings, but mainly compared with corresponding office buildings with large windows/glazed facades):

- Individual window ventilation is almost independent of wind and weather conditions, mainly during sunny winter days and the intermediate season (spring and autumn)
- Reduced heating demand thanks to preheating of outdoor air
- Night cooling of the building by opening the inner windows is possible if the façade is well ventilated
- Improved burglary protection thanks to two glazed skins
- Better sound proofing towards the outside e.g. at locations with heavy traffic, mainly during window ventilation
- More efficient exterior (intermediate) solar shading, as the shading can be used also during windy days

Potential problems with office buildings with double skin facades can be:

- Poorer cross ventilation and insufficient removal of heat from the offices rooms during windless periods, when ventilation is mainly provided for by natural ventilation
- Hot summer/spring/autumn days can lead to high temperatures in office rooms as a result of window ventilation
- Higher investment costs
- The office floor area can be reduced
- Risk of cross talk via façade from one office to another with open windows
- Cleaning can result in additional costs
- The energy saving potential has often been overestimated
- Fire protection can be more difficult depending on the typ of façade.

4 HVAC Aspects

by SKANSKA

HVAC (Heating, Ventilating, and Air Conditioning) is the system that maintains desired environmental conditions in a space in most modern buildings. In almost every application, several options are available to satisfy this basic goal. In the selection and combination of these options several criteria have to be considered to achieve the functional requirements associated with the goal.

The building has to fulfil certain performance requirements concerning indoor air quality, thermal comfort, and energy use. The requirements on indoor air quality mean that certain air flows and ventilation efficiency have to be obtained. The requirements on thermal comfort mean that the indoor environment must be kept at a comfortable level not too cool and not too warm. The requirements on energy use mean that the energy needed to operate the whole building and the energy use for heating and cooling the building in specific has to be optimised using e.g. heat recovery and free cooling, depending upon climatic conditions. Therefore a well controlled and energy-efficient ventilation system is a prerequisite for low energy consumption and an acceptable indoor climate. However, in most cases in thermally well insulated office buildings, the ventilation and cooling system, may account for more than 50% of the energy use.

Today, buildings should be designed to interact with the outdoor environment. Unfortunately, the design of energy-efficient ventilation systems in office and public buildings has often become a question of using mechanical ventilation.

4.1 Ventilation system

Ventilation is used for different purposes. Its principal purpose is to exchange contaminated air with clean and tempered air. It is also important to create a room climate without draught problems and only slight temperature changes in the occupied zone. Room climate depends on several factors, including air velocity, air temperature and radiant temperature. When people occupy rooms, significant changes in any of these factors can cause draught problems.

There are two main principles when ventilating a room:

Mixing ventilation

The mixing principle is characterized by a relatively high velocity of the supply air, which causes a high rate of induction of the room air. This creates movements of air which cause mixing to take place and thereby a uniform distribution of those contaminants which are produced in or enter the room. The temperature distribution in rooms ventilated by the mixing principle is also relatively even.

Displacement Ventilation

In this ventilation typ low velocity supply air is conducted by a high number of openings in one surface of the room and taken apart at the opposite surface. The inlet air therefore displaces the room air without mixing.

Thermally controlled ventilation

This ventilation type is characterized by low velocity supply air, which is at under-temperature. The thermal forces therefore control the flow to a larger extent than the dynamic forces. The movement of air in the room is thus determined largely by the density differential between the supply air and the room air, as well as by the positioning of the supply and exhaust units.

4.1.1 Basic principles and characteristic properties

There are different ventilation solutions that can be implemented to fulfil the demands for correct air flows to all parts of a system. The main categories are:

- CAV systems (Constant Air Volume), systems with constant air flows. The simplest and generally the "cheapest" alternatives.
- VAV systems (Variable Air Volume), systems with variable air flows, as a rule regulated by thermostats in each room. The fan is fitted with some form of pressure regulation device.
- DCV systems (Demand Controlled Ventilation), systems controlled by demand, as a rule regulated via an air quality or presence sensor.
- All system solutions can, of course, be designed for either mixing or displacement regulated ventilation.

Both CAV and DCV systems can be combined with different heating and cooling units for regulating the indoor temperature.

4.2 Thermal comfort

An acceptable room temperature is one which is not less than 18°C or more than 28°C. The comfortable temperature range is considerably narrower and normally falls between 20°C and 24°C. It is difficult to meet all requirements for a suitable temperature. Therefore, clothes are always to be considered as a comfort regulator.

It has been shown in several studies that mental performance and rate of work diminish significantly as the room temperature rises above 27°C. It is therefore easy to show that it is profitable to invest in suitable air-conditioning equipment.

One problem to bear in mind is that each person places an individual set of demands on the working environment. This means that it is essential to prioritise system solutions that are as flexible as possible, i.e. systems that make it possible to meet individual needs.

4.2.1 Perceived thermal comfort

Individuals perceive the climate as a joint action of several factors that affect our thermal comfort:

- Level of activity, the body's heat production
- Clothing's thermal resistance
- Ambient air temperature
- Surrounding surfaces' temperature
- The air's relative speed
- The air's relative humidity

According to Professor P.O. Fanger[1] the ideal indoor climate has been attained when people perceive thermal comfort, i.e. when a person is thermally neutral. However, one of the problems you always face when creating a good climate with the help of a climate system is that people perceive the climate differently.
No matter how well one succeeds, about 5% will still be dissatisfied. The percentage of those dissatisfied will then increase for each degree of deviation from the average person's most ideal climate condition.

4.2.2 Comfort cooling

The excess heat that must be removed from a building to keep the indoor temperature lower than a predetermined highest permitted temperature is known as the cooling requirement. The climate systems used to actively cool buildings can generally be divided up into three types.

- Systems with air based cooling
- Systems with water based cooling
- Combined systems (cooling is supply using both air and water)

[1] Fanger P. O. (1982) cit. in "The Ashrae Handbook of fundamentals", 2005

It is important to differentiate between the sensible cooling effect requirement and the total cooling effect including wet cooling. The sensible cooling effect refers to the output determined by the temperature difference between the required temperature and the temperature you would have without comfort cooling. The total cooling effect should also include the latent cooling requirement. This refers to the enthalpy difference that must be achieved in order for the supply air to be dehumidified in the ventilation unit's cooling coil. If the latent cooling requirement is included in general the total design cooling requirement increases significantly.

System with air based cooling

In these systems the design air flow is determined by the cooling requirement. That's to say it is the thermal demands and not the demands on the air quality that dictate the design.

In existing buildings it is normally both difficult and expensive to change the duct system. If sufficiently large air flows can't be transported in the existing ducts to satisfy the cooling requirement, usually a water based cooling system is installed during the renovation. The cooling system must have the capacity to take care of variations in the cooling requirement, both during the day and over the year. The two basic types of system with air based cooling are a constant flow system or a system with a variable flow (a combination of the two methods is also available).

System with constant air flow – CAV system

The CAV systems (Constant Air Volume) is characterised by the air flow being constant. The rooms with the greatest cooling requirement normally determine the selection of the supply air temperature prepared in the central air handling unit. In other rooms the air can be reheated.

Even if a CAV system supplies air at a constant flow sometimes fans with two-speed motors are used, this allows the speed to be decreased when the cooling requirement in the building so permits. The supply air temperature in a CAV system can be constant or variable. When temperature control takes place centrally or with a constant supply air temperature, a correction to the right room temperature is made during the winter in individual rooms, for example, using radiators.

Systems with variable air flow – VAV system

In VAV systems (Variable Air Volume) the air flow supplied to each room varies as required, yet the temperature of the supply air is kept constant, i.e. the supply air temperature does not change with a change in load. On the other hand, seasonal control of the supply air temperature takes place, as a function of the outdoor temperature.

The air flow to each room is controlled by a damper directly connected to the room, while central supply and exhaust air fans are controlled by means of guide vane control or speed controlled fan motors, usually frequency controlled. Control usually occurs to maintain a constant static pressure in one of the branch ducts furthest away. The flow varies from maximum on the hottest day down till approximately 20% of maximum during the year's coldest days, when the air only has the task of satisfying the demands on air quality.

Systems with water based cooling

These types of system supply the individual rooms with water based cooling. The air system used only satisfies the demands on air quality.
In a conversion or refurbishment situation it is preferable to use this type of cooling system. When installing the system there is usually space in the existing suspended ceiling to install the required pipes needed for the distribution of chilled water in the building.

Combined systems

Air based and water based cooling can be combined in many different ways. One situation when the systems must be combined is when the air based system does not have sufficient cooling capacity.

It is also possible to combine air based systems so that in specific parts of a building, or in specific rooms, a VAV system is used (by utilising VAV units on which the air flow can be controlled), and in remaining parts of the building a CAV system is used.

Conventional electrically driven compressor cooling

Cooling generation using a compressor cooler is the "classic" method for cooling. When mechanical cooling for comfort cooling is discussed this is usually considered to be the standard.

Using a compressor driven chiller gives you immense flexibility with regard to the methods of supplying cooling to the building. As previously mentioned it is possible to deliver cooling from chillers either to the cooling battery in an air treatment unit or to cooling equipment placed directly in the room, for example, chilled beams or fan coil units.

Evaporative cooling

Evaporative cooling of air utilises the fact that the air's temperature drops by making it moist with the help of water evaporation from a wet area that the air passes. Cooling is possible as long as the air is not saturated with water vapour. The lowest temperature the air can take with this type of cooling is limited by the air's wet temperature, which is sometimes called the air's cooling limit.

Direct evaporative cooling refers to a process where the supply air is moistened and the temperature drops. At the same time the air’s moisture content increases. With indirect evaporative cooling the exhaust air is moistened, whereby the exhaust air’s temperature drops. This is followed by a heat exchange (without moisture transfer) between the exhaust and supply air where the heat from the supply air can be transferred to the exhaust air.

The possibility to cool is mainly determined by the current condition of the outdoor air. The more moisture (the higher tweet value) it contains the poorer its ability to cool. Consequently, the method is considered to have limited use in offices and other commercial premises.

Sorption cooling

In order to lower the temperature of the supply air as far as possible, it is beneficial to have the driest possible air when moistening starts. In the sorption cooling process moistening from the evaporative process is supplemented by drying of the supply air before it is moistened.

A sorption cooling unit consists of a dehumidifier section that dries the air and a section that cools the air (the evaporative part). The supply air is dehumidified using a moisture absorbing rotor. On the exhaust air side the absorbed water is driven out of the rotor. Heat is used for this. Accordingly a sorption cooling unit also needs to supply heat.

District cooling

In Sweden it is becoming increasingly common for energy companies to offer their customers district cooling. Depending on the requirements of each individual energy company concerning the production possibilities and the layout and proximity of customers, cooling is produced and distributed in different ways in different districts. In a district cooling system production units can be made up of everything from “free cooling” (e.g. cold sea water that can be utilised directly for cooling purposes), compressor coolers, to heat driven cooling machines.

It is relatively common to utilise cooling from existing heat pumps that are already used to deliver heat to the district heating system. Initially it was usual that users with a relatively large cooling requirement were connected to the district cooling system. This typically could be a hospital area or a shopping centre. However, it is becoming more common that individual properties are being offered the opportunity of being connected.

“Chilled water” is delivered to the customer in a substation, in principle the same way as a subscriber centre for district heating. From here secondary water is distributed to the building or buildings to be cooled.

Free cooling

There is a possibility with water based cooling systems to use what is known as free cooling. Here it is necessary to install some form of heat exchanger to the outdoor air. This is usually integrated in the comfort cooling unit. A heat exchanger is connected between the liquid cooler unit's refrigerant and cooling medium circuits.

In connection with the utilisation of free cooling when using water based cooling it is common that at a predetermined outdoor temperature you allow all water to be cooled against the outdoor air. Accordingly, at lower temperatures than this temperature the cooler is not used. The outdoor temperature at which switching occurs normally lies around 10°C.

4.3 Double Skin Façades buildings and HVAC

There are two different approaches:

1. A building with its own separate heating, cooling and ventilating system, where a second skin is added to the façade. The cavity of the double skin façade is only ventilated to the outside and is built to reduce noise, contain solar shading and light redirection devices.
2. A building, where the heating, cooling and ventilating system of the building is integrated into the double skin façade e.g. by ventilating the building using the cavity of the double skin façade.

Alternative 2 is often the most cost effective alternative. The first alternative risk being a building with a complete conventional HVAC system, with the added cost of an expensive façade. Most of the above described HVAC systems can be applied to buildings with double skin facades. According to different investigations and technical reports there are some technical benefits with a DSF, benefits which have an impact on the HVAC system.

- All types of Double Skin Façade offer a protected place within the air gap to mount solar shading and daylight enhancing devices, which then can be used whenever necessary and thereby reducing the cooling load
- One of the main advantages of the Double Skin Façade systems is that they may allow natural (or fan supported) ventilation, which will reduce the use of electricity for ventilation.
- In winter the cavity forms a thermal buffer zone which reduces heat losses and enables passive thermal gain from solar radiation, which will reduce the heating load.
- May enable natural ventilation and night time cooling of the building's thermal mass, which will reduce the use of electricity for ventilation and the cooling load.
- Noise reduction from motor traffic, enabling natural ventilation without noise problems.

5 Literature Database

As a basis for the further research work a general literature database was established with contributions from all partners of the project.

5.1 Approach and options of the literature database

A centralised information system database containing literature about double skin facades has been created in the framework of the work package 1. The literature database is the knowledge base for further work in the Bestfaçade work packages such as non technological barriers, benchmarks, calculation method up to the dissemination activities.
The aim of this literature database is to give all partners an overview about the state of the art concerning the published and relevant literature in the field of double skin façades.
This new Access database of documents about double skin facades has been created in June 2005, in the framework of the Bestfaçade project.

Fig. 10 main menu of the Bestfaçade literature database

The database contains references of articles, books, proceedings, diploma thesis and PhD thesis about double skin facades. These documents may be sorted and evaluated by their authors, keywords, language and publication type, with the objective to make it as easy as possible to find a special document or documents about a special aspect of double skin facades.
The main function and advantage of this database is the possibility to get an efficient overview about the literature, ranked by keywords and their relevance in this document.

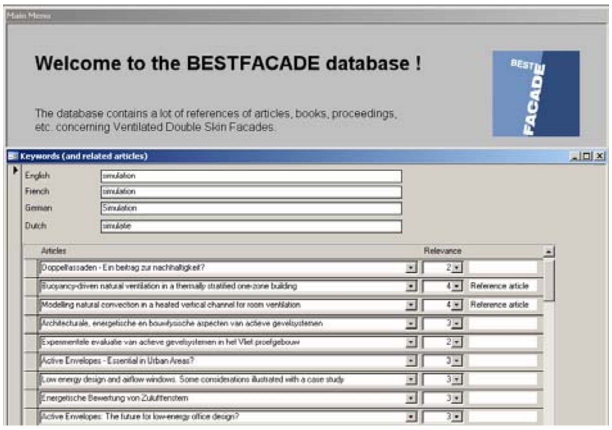

Fig. 11 menu item – keywords (simulation) and the related articles

The second main advantage is the possibility to include all the literature references as a full-text file (PDF-file numbered with the database ID-number of the database entry).
An index file was created for the collected PDF-files, including all the search strings for a fast seeking and finding within all the PDF-files.

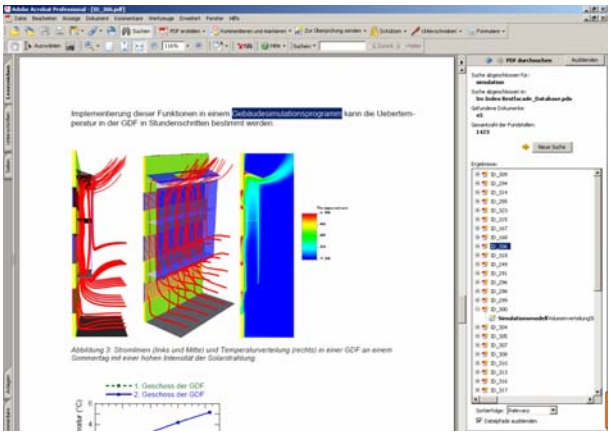

Fig. 12 PDF-search results – sought word (simulation), the related articles and the position of the search strings inside the different PDF-files

5.2 Activities and realisation of the literature database

The literature database, based on a national research project, financed by the Belgian Federal Public Service Economy [LIT source BBRI], was created by BBRI. In June 2005, the adoption of an existing BBRI database of double skin facades to the Bestfaçade needs by BBRI and IWT was finished. A new article interface accrues in this version, including all the necessary information's about the relevant documents .

Each partner of the Bestfaçade project has provided his own literature references. There is one responsible person for the literature database per country. The database has been sent around and stayed for two weeks in each country to input the data. The check of the database (e.g. doubling, correct input,...) has been done by IWT.

During this time period the partners included their own known articles. The following information about the literature was asked.

- Article_ID: identification number of the article
- Title: the title of the article
- Publication type: the most appropriate type among the several possibilities
- References: the reference of the article (e.g.: name of the conference, website, etc.)
- Language: the language of the article (max. two languages for one article)
- Pages: the number of pages
- Date: the date of the publication of the article
- PDF: the abstract of the article is available in the PDF format (with or without rights) / the full text of the article is available in the PDF format (with or without rights)
- Hard copy available: the hard copy of the article is available in the office of the specified partner
- Partner: the partner (=institute) that has encoded the article
- Reporter: the person who has encoded the article
- Image: the image of the front page of a book (dimension of the picture approximately 172 x 190 Pixels, maximum number of pictures colours is 256)
- Authors: the author's name
- Keyword: one or more keywords, which are relevant for the article
- Relevance: the degree of relevance (-1 = no interest ; 4 = high interest) for each mentioned article – keyword

After this first round more than 360 articles are available within the literature database. A second upgrading of the literature database is planned for the last year of the Bestfaçade project.

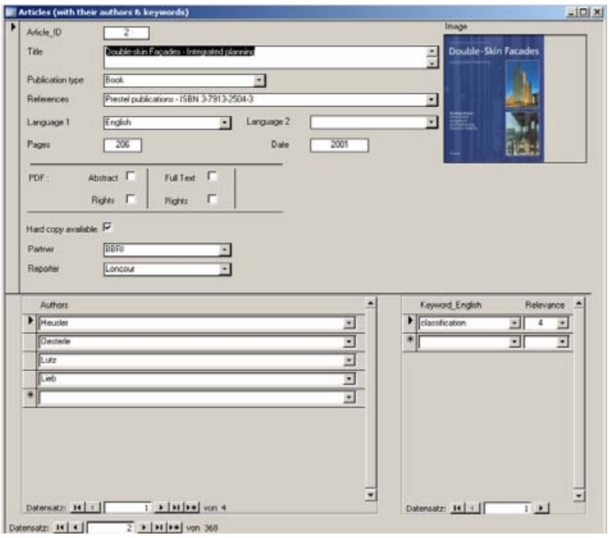

Fig. 13 menu item – input mask of the database with all relevant article input files

A special four-language keyword list (English, French, Dutch and German) was developed to classify the literature by reducing and completing an existing list from BBRI. This keyword list is the main feature for finding and using the literature database.

English	French	Dutch	German
acoustics	acoustique	akoestiek	Akustik
cavity climate	climat dans la cavité	klimaat in the spouw	Klima Fass.zwischenraum
classification	classification	classificatie	Klassifikation / Gliederung
comfort	confort	comfort	Komfort
construction details	details de construction	bouwdetails	Konstruktionsdetails
control systems	systèmes de contrôle	regelsysteem	Regelungssystem
cooling	refroidissement	koeling	Kühlung
design	conception	ontwerp	Konzeption
economical aspects	aspects économiques	economische aspecten	wirtschaftliche Aspekte
energy	énergie	energie	Energie
field test	essai sur terrain	test te velde	Feldversuche
fire safety	protection incendie	brandveiligheid	Feuer / Brandschutz
glazing	vitrage	beglazing	Verglasung
heating	chauffage	verwarming	Heizung
history	histoire	geschiedenis	Geschichtliches
in situ measurement	mesures in situ	in situ metingen	'in situ' Messungen
indoor climate	climat intérieur	binnenklimaat	Raumklima
labtest	essai laboratoire	labtest	Labortest
lighting	éclairage	verlichting	Licht
maintenance	maintenance	onderhoud	Instandhaltung
material	matériau	materiaal	Material
motivation	motivation	motivatie	Motivation
pathology	pathologie	pathologie	Bauschaeden
performance	performance	prestatie	Leistungsfähigkeit
regulation / standardization	réglementation / norme	regelgeving / norm	Reglementierung / Normung
renovation	renovation	renovatie	Sanierung
shading / glare	eblouissement	zonnewering / verblinding	Sonnen- / Blendschutz
simulation	simulation	simulatie	Simulation
ventilation	ventilation	ventilatie	Lüftung

Fig. 14 29 defined keywords for the field of research
on double skin facades listed in four languages

Each partner, filling the literature database, has added also some, the paper describing keywords. Each of these keywords got on relevance-value (-1 = no interest; 4 = high interest), rating the article importance concerning to the chosen keyword.
This relevance-value allows now a very fast overlook about the keyword related articles, finding out the 'best rated paper'.

5.3 Statistical analysis literature database

In this chapter a statistical analysis of the literature database is shown. This analysis includes on the one side the statistics about the inputs of the partners and on the other hand the statistics about the articles itself.

General items

The main languages within the collected literature entries in the field of double skin facades are English (48%), German (26%), Dutch (14%) and French (11%). The PDF-Articles are not translated and so the articles are only in the original language available.

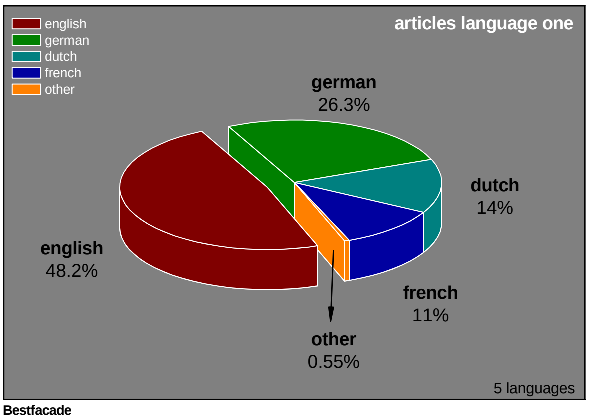

Fig. 15 Apportionment of article languages within the literature database

An important aspect for the quality of the literature database is the distribution of the publication types within the literature database. The main part are common articles (38%), proceedings (32%) followed by books (6%), presentations (5%), PHD Thesis (4%) and so on.

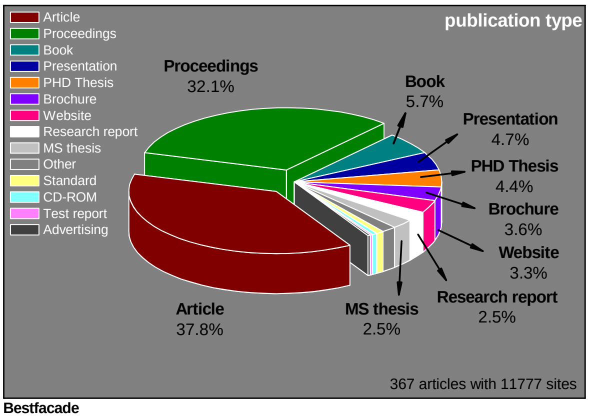

Fig. 16 Apportionment of publication types within the literature database

Keywords versus number of articles

In the figure below the number of articles per keywords (right y-axis) can be seen. 70% of these articles can be described using the following nine keywords, simulation, design, energy, ventilation, performance, classification, comfort, cavity climate and control systems. The remaining 30% of articles are related to the rest of the keywords (20 pieces of keywords).

On the left y-axis is the average relevance per keyword diagrammed. With this bars it’s possible to find the keywords with high or low relevance.

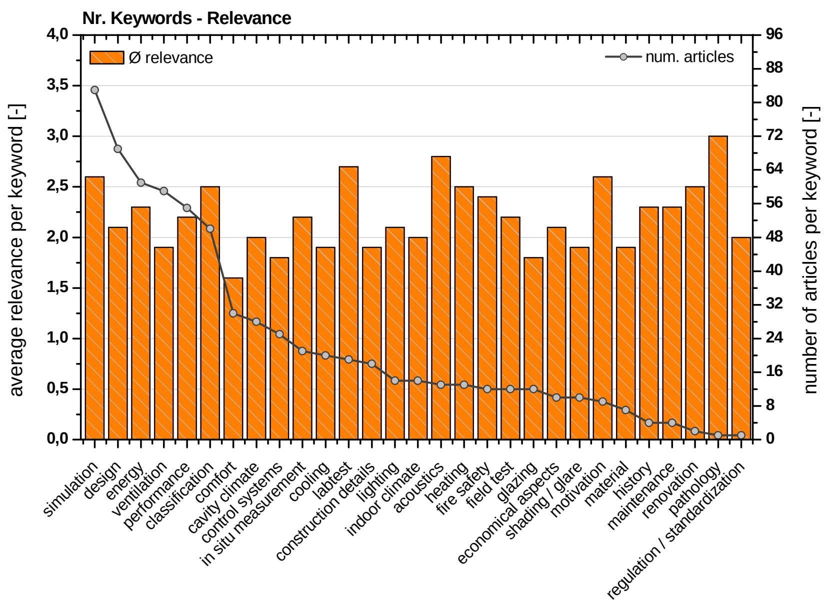

Fig. 17 Number of the articles per keyword versus the average relevance per keyword

The fields of the keywords with a large number of articles (>50) are well researched. These keywords can be sorted by the average relevance. Therefore we have six keywords corresponding to these conditions.
The keywords 'simulation' and 'classification' have the best average relevance values. These investigated subject areas contain useable scientific results.
The keywords 'design' and 'ventilation' are with a large number of articles but with less relevance value. In this subject areas further research seems necessary.

Keyword	Nr. Article	Relevance
simulation	83	2.6
classification	50	2.5
energy	61	2.3
performance	55	2.2
design	69	2.1
ventilation	59	1.9

Fig. 18 Keywords with more than 50 articles sorted by average relevance

The researched areas which keywords occur in a low number of articles (<12) are investigated not so often. These keywords are sorted by the average relevance. Therefore we have nine keywords corresponding to these conditions.
The keywords 'pathology' and 'motivation' have the best average relevance values. This badly investigated subject areas (one and nine articles) contain useable scientific results but further research work is necessary.
The keywords 'material' and 'glazing' are with a low number of articles and with a bad relevance value. In this subject areas further research seems urgent necessary.

Keyword	Nr. Article	Relevance
pathology	1	3
motivation	9	2.6
renovation	2	2.5
history	4	2.3
maintenance	4	2.3
economical aspects	10	2.1
regulation / standardization	1	2
material	7	1.9
glazing	12	1.8

Fig. 19 Keywords with less than 12 articles sorted by average relevance

The best articles and authors (with PDF-files)

In the following table are the best weighted PDF-files, included within the database, shown. The articles are all with a maximum relevance of four, sorted by the keywords. Only for eight keywords corresponding full-text papers are included. The complete list, sorted by keywords, can be found in the appendix.

Relevance	Article_ID	Article_Title
acoustics		
4	237	Acoustical Performances of Double Ventilated Glass Façades The 33rd International Congress and Exposition on Noise Control engineering, Prague, 22 - 25 August 2004
4	286	Performances acoustiques des doubles façades ventilées Les dossiers du CSTC, Cahier Nr 1, 4ème trimestre 2004, page 1
4	287	Akoestische prestaties van dubbele geventileerde gevels WTCB Dossiers, Kartern Nr 1, 4de trimester 2004, pagina 1
4	288	Les doubles façades ventilées : performances acoustiques CSTC Contact, Nr 4, Décembre 2004, p 3
4	289	Dubbele geventileerde gevels : akoestische prestaties WTCB Contact, Nr 4, December 2004, p 3
classification		
4	18	Ontwerpen - fabriceren en monteren op de bouwplaats van klimaatgevels en 2 huid façades TU Delft / Faculteit Bouwkunde (The Netherlands) - 23/10/1996 - ISBN 90-5269-221-1 geb
4	236	Dubbele Geventileerde Gevels - Deel 1 : Voorstelling van de gevelopbouw WTCB Dossiers, Kartern Nr 1, 1ste trimester 2004, pagina 1
4	235	Les Doubles Façades Ventilées - 1ere Partie : illustration des concepts de façade Les Dossiers du CSTC, Cahier Nr 1, 1er trimestre 2004, page 1
4	234	Dubbele Geventileerde Gevels WTCB Contact, Nr1, Maart 2004, p 3
4	233	Les Doubles Façades Ventilées CSTC Contact, Nr1, Mars 2004, p 3
4	64	La façade double peau EPFL - Institut technique du bâtiment - département d'architecture
construction details		
4	18	Ontwerpen - fabriceren en monteren op de bouwplaats van klimaatgevels en 2 huid façades TU Delft / Faculteit Bouwkunde (The Netherlands) - 23/10/1996 - ISBN 90-5269-221-1 geb
energy		
4	117	An investigation into the use of a supply air window as a heat reclaim device Proceedings CIBSE - A building Serv. Eng. Res. Technol. 20(3) 105-112 (1999)
labtest		
4	117	An investigation into the use of a supply air window as a heat reclaim device Proceedings CIBSE - A building Serv. Eng. Res. Technol. 20(3) 105-112 (1999)
lighting		
4	64	La façade double peau EPFL - Institut technique du bâtiment - département d'architecture
simulation		
4	176	Building Simulation - Some swiss experiences Seventh International IBPSA Conference, Rio de Janeiro, Brazil, August 13-15, 2001, p 505 - 512
4	69	Etude du bilan énergétique de la façade double-peau et de son influence sur le comportement du bâtiment EPFL, Master européen en architecture et développement durable
ventilation		
4	235	Les Doubles Façades Ventilées - 1ere Partie : illustration des concepts de façade Les Dossiers du CSTC, Cahier Nr 1, 1er trimestre 2004, page 1
4	117	An investigation into the use of a supply air window as a heat reclaim device Proceedings CIBSE - A building Serv. Eng. Res. Technol. 20(3) 105-112 (1999)

Fig. 20 The full-text articles with maximum relevance, sorted by keywords

All authors, with more than three full-text articles are shown in the table below (sorted by relevance).

Author	Nr. Article	Relevance
Crispin	3	3.39
Ingelaere	3	3.39
Loncour	7	2.86
Kragh	4	2.50
Hensen	6	2.24
Boake	5	2.00
Saelens	3	2.13
Wind	4	-

Fig. 21 The authors with more than three full-text articles, sorted by relevance

The fifteen best rated full-text articles and their authors are shown in the following table . The article 'An investigation into the use of a supply air window as a heat reclaim device' from Baker and McEvoy (with the article ID 117) has got an average relevance-value of 3.75, over four mentioned keywords.

Author	Article_ID	Title	Nr.Keywords	Relevance
Baker	117	An investigation into the use of a supply air window as a heat reclaim device	4	3.75
Mc Evoy	117	An investigation into the use of a supply air window as a heat reclaim device	4	3.75
Augenbroe	235	Les Doubles Façades Ventilées - 1ere Partie : illustration des concepts de façade	4	3.50
Ingelaere	286	Performances acoustiques des doubles façades ventilées	3	3.33
Crispin	286	Performances acoustiques des doubles façades ventilées	3	3.33
Martin	289	Dubbele geventileerde gevels : akoestische prestaties	3	3.33
Loncour	289	Dubbele geventileerde gevels : akoestische prestaties	3	3.33
Crispin	287	Akoestische prestaties van dubbele geventileerde gevels	3	3.33
Blasco	289	Dubbele geventileerde gevels : akoestische prestaties	3	3.33
Blasco	288	Les doubles façades ventilées : performances acoustiques	3	3.33
van de Linde	18	Ontwerpen - fabriceren en monteren op de bouwplaats van klimaatgevels en 2 huid façades	3	3.33
Blasco	287	Akoestische prestaties van dubbele geventileerde gevels	3	3.33
Blasco	286	Performances acoustiques des doubles façades ventilées	3	3.33
Loncour	288	Les doubles façades ventilées : performances acoustiques	3	3.33
Loncour	236	Dubbele Geventileerde Gevels - Deel 1 : Voorstelling van de gevelopbouw	3	3.33

Fig. 22 The authors and their full-text articles, with more than three keywords, sorted by relevance

Age of the literature database

The age of the articles, included into the literature database can be seen in the figure below. The average age of the articles is about four years , the oldest article is about 22 years old and the newest article is about three month old. The actuality of the database literature is fine and thus a well starting point for the further working packages.

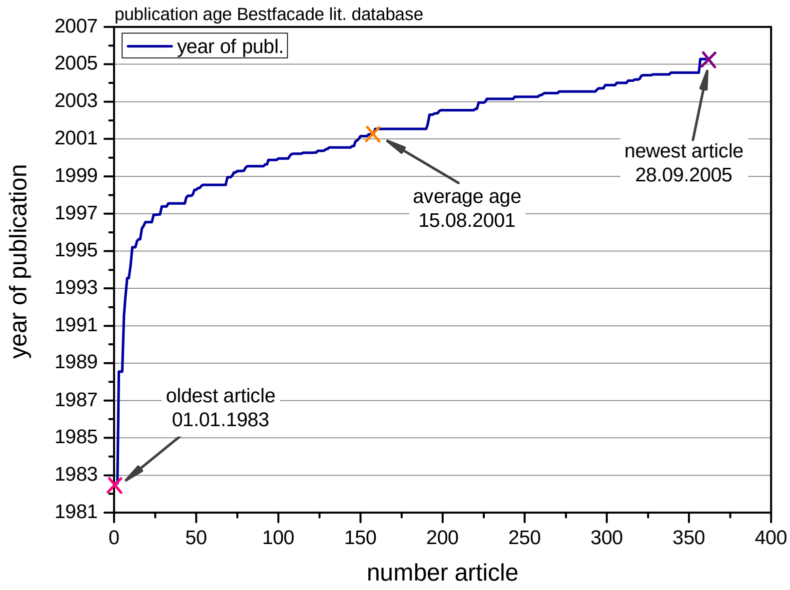

Fig. 23 age of the articles included into the literature database

5.4 Appendix

How to introduce new articles in the Bestfaçade database?
This report shows the way to include new articles into the Bestfaçade literature database.

Evaluated Bestfaçade literature database

- All articles sorted by the ID number with the title, the reference, the date and the information about the available full-text PDF file.
- All articles sorted by the author, including the title, the reference, the date and the information about the available full-text PDF file.
- All articles with a maximum relevance of four, sorted by the belonging keywords.
- All full-text articles with a maximum relevance of four, sorted by the belonging keywords.
- All articles with relevance greater equal two, sorted by the belonging keywords.
- All full-text articles with a maximum relevance greater equal two, sorted by the belonging keywords.

Full-text literature folder

The folder 'Literature' contains all 161 collected PDF-files. The PDF-Index file, for a fast string search within all the full-text files, can be found at the folder 'Index_Database' (Bestfacade_Database.pdx). The recommended program is the free Adobe Acrobat viewer which can be downloaded at the Acrobat homepage.

6 Standard protocol of information for double skin facades

Besides the establishment of the literature database the collection of implemented Double Skin Façades in the member countries of the project was the main goal of WP 1. In order to collect data on a comparable basis two questionnaires (a short and a detailed one) were developed by IWT and ISQ supported by all other participants as standard protocol of information (photographs, diagrams, performance data and graphs etc.). This information perform the basic resources for the following WPs and on the other hand give an overview of DSF in Europe on the web site. Both questionnaires were deeply discussed during the second project meeting in Holzkirchen, Germany in June 2005.

It was decided, that as a first step the short questionnaire which gathers information about the building (address, involved institutions and companies, the room heating and cooling system including its energy demand, the room ventilation and the local energy tariff) and information of the façade system (geometry, type and costs) should be send to all participants in order to have a high number of double skin facades described.

For many of the items in the questionnaire an online explanation is available. This short questionnaire of WP1 was sent out hand in hand with a comfort questionnaire for users and office managers, developed by ISQ for WP3.

The detailed questionnaire, taking into account also measured data about temperatures in the façade gap and indoors, the detailed control of ventilation, shading, and other features was sent out in a second round where at least three facades per country should be described in all the details needed in the following WPs. It comprised items such as: detailed questions on the specific climate, existing simulations and measurements, thermal behaviour, indoor air quality, comfort, user acceptance, energy demand and consumptions (heating, ventilation, cooling, lighting), control strategies, integrated building technology, costs (investment, maintenance, operation), resource conservation, environmental impact, comparison to conventional facades, renewable energy sources, integration into DSF, non-energy related issues like acoustics, aesthetics, fire protection, moisture, corrosion, durability, maintenance, repair. Both questionnaires can be found in the appendix.

Included is a coherent typology of double skin facades merged by several information sources (BBRI and others), where the façade type can be defined by click boxes. Though DSF might be classified by at least three methods as mentioned in the following it was decided to use the classification according to the partitioning of the gap. First because this method is highly reputed in the literature[1], secondly because it might be the most interesting

[1] Gertis, K.: „Sind neuere Fassadenentwicklungen sinnvoll? Teil2: Glas-Doppelfassaden“ Bauphysik 21 (1999), Heft 2, S. 54-66

Lang, W.: Typologische Klassifikation von Doppelfassaden und experimentelle Untersuchung von dort eingebauten Lamellensystemen aus Holz zur Steuerung des Energiehaushaltes hoher Häuser unter besonderer one for architects who in most cases are the initiators of DSF and therefore should receive analysis data in a most comprehensive way and thirdly because the partitioning of the gap is the most visible classification of DSF which easily can be evaluated by everyone facing such a façade without being obliged to get additional data of building technologies behind.

6.1 Coherent typology of double skin façades

As mentioned above there are many different principles of how to construct ventilated double skin façades. These can be classified according to three different criteria which are independent of one another and are based not only on the geometric characteristics of the façade but also on its mode of working. These are: Type of ventilation, Ventilation mode of the cavity, Partitioning of the façade[1].

6.1.1 Type of ventilation

The type of ventilation refers to the driving forces at the origin of the ventilation of the cavity located between the two glazed façades. Each ventilated double skin façade concept is characterised by only a single type of ventilation. One must distinguish between the three following types of ventilation: natural, mechanical or hybrid ventilation (mix between natural and mechanical ventilation).

6.1.2 Ventilation mode of the cavity

The ventilation mode refers to the origin and the destination of the air flowing in the ventilated cavity. The ventilation mode is independent of the type of ventilation applied (the first classificatory criterion presented).
Not all of the façades are capable of adopting all of the ventilation modes described here. At a given moment, a façade is characterised by only a single ventilation mode. However, a façade can adopt several ventilation modes at different moments, depending on whether or not certain components integrated into the façade permit it (for example operable openings). One can distinguish between the following five main ventilation modes:

Berücksichtigung der Nutzung von Solarenergie Dissertation, München, 2000
Zöllner, Andreas: Experimentelle und theoretische Untersuchungen des kombinierten Wärmetransports in Doppelfassaden. Diss. München, 2001

[1] Loncour, X., Deneyer, A., Blasco, M., Flamant, G., Wouters, P.: Ventilated Double Skin Facades - Classification & illustration of facade concepts, BBRI – Department of Buildings Physics, Indoor Climate & Building Services, 2005

Outdoor air curtain

In this ventilation mode, the air introduced into the cavity comes from the outside and is immediately rejected towards the outside. The ventilation of the cavity therefore forms an air curtain enveloping the outside façade.

Indoor air curtain

The air comes from the inside of the room and is returned to the inside of the room or via the ventilation system. The ventilation of the cavity therefore forms an air curtain enveloping the indoor façade.

Air supply

The ventilation of the façade is created with outdoor air. This air is then brought to the inside of the room or into the ventilation system. The ventilation of the façade thus makes it possible to supply the building with air.

Air exhaust

The air comes from the inside of the room and is evacuated towards the outside. The ventilation of the façade thus makes it possible to evacuate the air from the building.

Buffer zone

This ventilation mode is distinctive inasmuch as each of the skins of the double façade is made airtight. The cavity thus forms a buffer zone between the inside and the outside, with no ventilation of the cavity being possible.

6.1.3 Partitioning of the façade

The partitioning of the cavity gives the information on how the cavity situated between the two glazed façades is physically divided. The partitioning solutions implemented in practice can be classified as follows:

Double window ("box-window")

A façade equipped with a ventilated double window is characterised by a window doubled inside or outside by a single glazing or by a second window. From the partitioning perspective, it is thus a window which functions as a filling element in a wall. Some concepts of naturally ventilated double windows are also called ´Box-window´ in the literature.

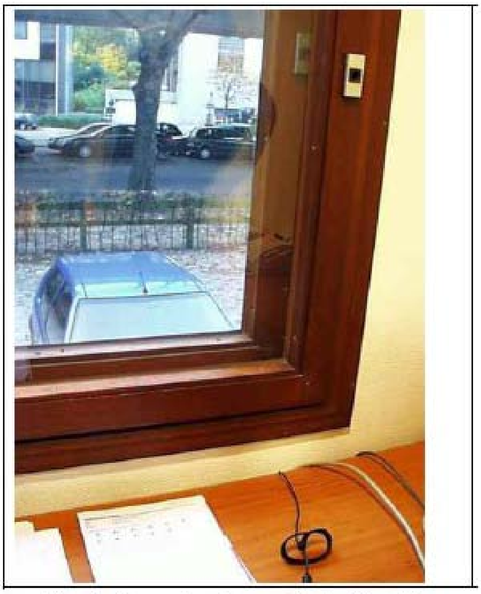

Fig. 24 Ventilated Double Window

The double façade partitioned per storey with juxtaposed modules

In this type of façade, the cavity is physically delimited (horizontally and vertically) by the module of the façade which imposes its dimensions on the cavity. The façade module has a height limited to one storey.

Fig. 25 Façade partitioned per storey with juxtaposed modules

The corridor-type double façade partitioned per storey

Those façades are characterised by a large cavity in which it is generally possible to walk. While the cavity is physically partitioned at the level of each storey (the cavities of each storey are independent of one another), it is not limited horizontally, and generally extends across several offices or even an entire floor.

Fig. 26 Ventilated double façade partitioned per storey

The ´Shaft-box´ double façade

The objective of this partitioning concept is to encourage natural ventilation by adapting the partitioning of the façade so as to create an increased stack effect (compared to the naturally ventilated façades which are partitioned by storey). Thus it is logical that this type of façade and partitioning is applied only in naturally ventilated double façades.

This type of façade is in fact composed of an alternation of juxtaposed façade modules partitioned by storey and vertical ventilation ducts set up in the cavity which extends over several floors. Each façade module is connected to one of these vertical ducts, which encourages the stack effect, thus supplying air via the façade modules. This air is naturally drawn into the ventilation duct and evacuated via the outlet located several floors above.

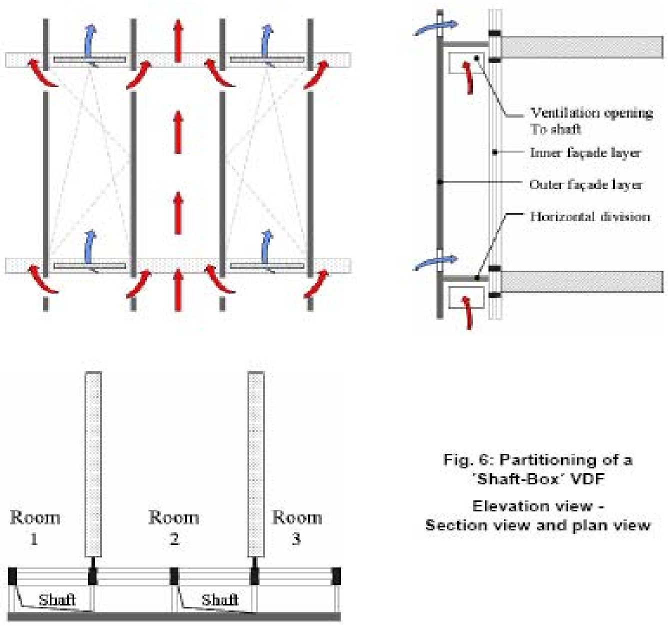

Fig. 27 Shaft-box´ ventilated double façade

The multi-storey double façade

Multi-storey ventilated double façades are characterised by a cavity which is not partitioned either horizontally or vertically, the space between the two glazed façade layers therefore forming one large volume. Generally, in this type of façade, the cavity is wide enough to permit access to individuals (cleaning service, etc.) and floors which can be walked on are installed at the level of each storey in order to make it possible to access the cavity, primarily for reasons of cleaning and maintenance.
In some cases, the cavity can run all around the building without any partitioning. Generally, the façades with this type of partitioning are naturally ventilated; however, there are also examples of façades of this type which are mechanically ventilated.
It should be noted that the façades of this type generally have excellent acoustical performances with regard to outdoor noise. This characteristic can be the reason for applying this particular type of façade.

Fig. 28 Multi-storey double façade

The multi-storey louver double façade

The multi-storey louver naturally ventilated double façade is very similar to a multi-storey ventilated double façade. Its cavity is not partitioned either horizontally or vertically and therefore forms one large volume. Metal floors are installed at the level of each storey in order to allow access to it, mainly for cleaning and maintenance.

The difference between this type of façade and the multi-storey façade is that the outdoor façade is composed exclusively of pivoting louvers rather than a traditional monolithic façade equipped (or not) with openings. This outside façade is not airtight, even when the louvers have all been put in closed position, which justifies its separate classification. However, the problems encountered with these façades are generally comparable to those encountered in the other ventilated double skin façades.

Fig. 29 Ventilated double façade with louvers, a: View of the louvers in horizontal position, b: View of the large cavity and the louvers in vertical position, Berlaymont 'building' Architect : Berlaymont 2000 s.a., P. Lallemand, S. Beckers

These classificatory criteria can be combined amongst themselves so as to form all of the ventilated double facades concepts imaginable (on the basis of these criteria). These various combinations are illustrated in the figure below.

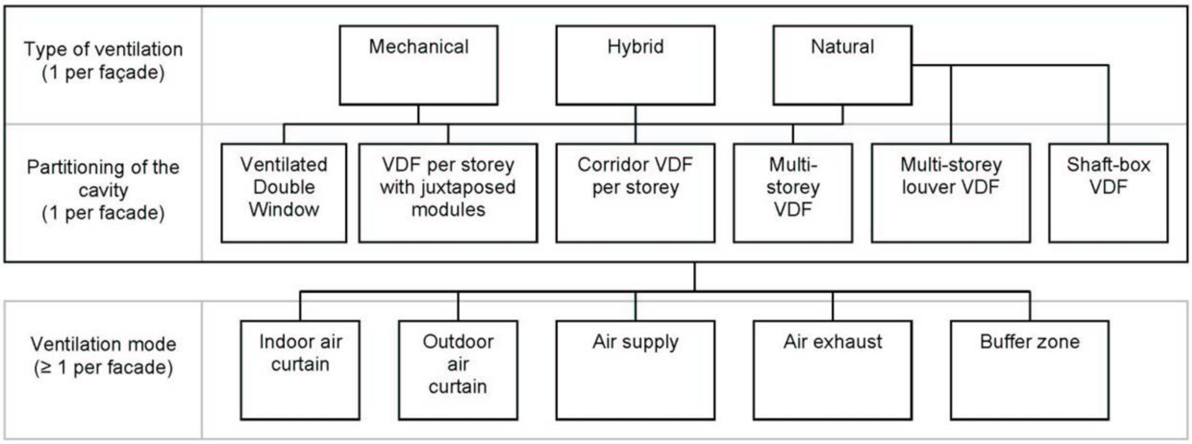

Fig. 30 Typology overview. VDF means DSF [BBRI[1]]

[1] X. Loncour, A. Deneyer, M. Blasco, G. Flamant, P. Wouters: Ventilated Double Skin Facades - Classification & illustration of facade concepts, BBRI – Department of Buildings Physics, Indoor Climate & Building Services, 2005

Not all of these imaginable concepts are applied in practice. The concepts which are applied in practice are not applied in all climates. Indeed, most of the facade concepts are more specifically adapted to one particular type of climate. Some partitioning of the cavity are applied only in naturally ventilated double facades.

6.2 Typology in different countries

For **Austria** the aim was to cover as many as possible different sizes, types and utilisations of buildings with DSF e.g. newly built DSF as well as retrofitted ones, offices as well as schools and museums. But unfortunately the smallest as well as the biggest examples as well as the most extraordinary one couldn’t be researched at the end - although managers of all of them showed high interest in joining the project at the beginning.
The small one is just two stories high and retrofitting the three facades of the control room of the fire brigade in Graz. The main purpose was to improve noise protection and thermal efficiency. Both aims are said to be achieved by the attached single pane façade with ventian blinds inside the gap.

Fig. 31 Control room fire brigade Graz. The old wooden windows have been left as they were

The large building would have been one of the largest researched building in the project: the Uniqa Tower in Vienna which consists of 24 stories and is said to be one of the most interesting towers among the aspiring high rises in Vienna for it’s HVAC concept and the good performance of it’s DSF. Probably there will be a chance to get data from this tower in coming spring.


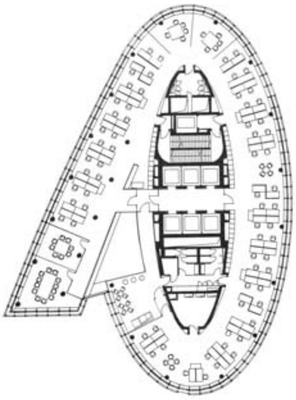


Fig. 32 Uniqa Tower, Vienna

The third interesting building which should have been covered is the "Kunsthaus Bregenz" which is well known for it's architecture. Since the walls of this museum have to be opaque due to presentation reasons in this case the DSF is used to provide daylight for special light ceilings in each story.


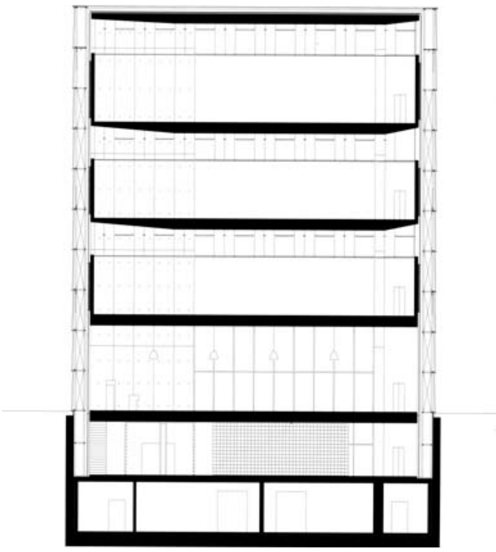

Fig. 33 Kunsthaus Bregenz

Besides the buildings descriebed above a special type could be covered in the analysis too. In the façade of BiSoP / Baden the open able windows are bypassing the gap - which might to be a good compromise to use the interesting aesthetics of DSF and at the same time avoids many disadvantages such as overheating, condensation and sound transmission. Of course this limits the height of the building if natural window opening should be possible, and may cause constructional disadvantages if very many windows are to be opened.

Fig. 34 BiSoP baden, north elevation

In **Belgium** there is a specific situation concerning the concepts of ventilated double skin façades. Indeed, a national project has shown that the big majority of VDSF - as DSF are called there - are of the same concept. This is an industrialised façade concept; the façade is partitioned per storey with juxtaposed modules and characterised by a single ventilation mode: the indoor air curtain. The facade is used to extract the air from the room with which it is in contact (indoor air curtain). Usually, for the big majority of buildings, not only the ventilated double skin façade but also the HVAC equipment is of the same kind.

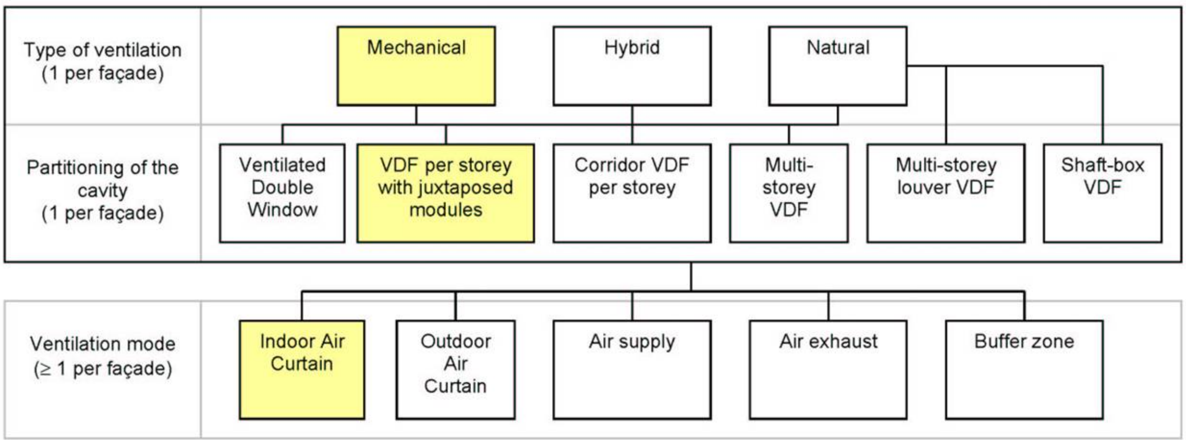

Fig. 35 The typical Belgium DSF typ within the multitude of varieties (VDF means DSF)

In **Portugal** DSF buildings are located mainly in Lisbon, where different architects have designed several high rise DSF buildings. These are mainly privately owned office buildings, some of them belonging to important Portuguese financial institutions. In fact, DSF were already being designed in Portugal in the 1980 – Caixa Geral de Depósitos, Av. da República -, currently, different typologies coexist in the city of Lisbon. These buildings have usually more than five storeys and the most common typologies are corridor façades and multi-storey façades. Aesthetical and energy conservation reasons are some of the main reasons that architects use to support the use of DSF. Despite the significant number of DSF buildings in Lisbon, and according to the information gathered, until now no comprehensive energetic/acoustic/lighting/user acceptance study of Portuguese DSF has been made.

In **Sweden** the interest among architects in applying the technique of double skin glass facades mainly in new construction of office buildings has increased during the last years. Such buildings have been built primarily in the Stockholm area e.g. Kista Science Tower, the ABB-house, the new police house, Glashusett and the Arlanda Terminal F, but also in the other Scandinavian countries. All in all there are about ten modern glazed office buildings with double skin facades in Sweden. The purpose of the double skin has in these cases been to reduce high indoor temperatures with protected efficient exterior solar shading during summer and reduce transmission losses during winter, and in some cases also to reduce noise from motor traffic. The double skin façade in Scandinavia has very seldom been used for ventilation of the building behind.

Modern office buildings in Sweden have high energy savings potential and potential for indoor climate improvements. They may have a lower energy use for heating, but does on the other hand often have a higher use of electricity than older office buildings.

Why are offices with fully glazed facades being built in Sweden? Architecturally an airy, transparent and light building is created, with more access to daylight than in a more traditional office building[1].

Technically it is possible to have a protected "exterior" movable efficient solar shading, to reduce noise from motor traffic and to open windows for ventilation during part of the year[2].

For Swedish conditions buildings with double skin facades are of interest for the same cases as in Germany i.e. mainly for high-profile-quality office buildings (new construction) and when a building envelope with transparency and lightness with regard to use of daylight and aesthetics is desired.

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[1] Svensson, A., Åqvist, P.: Double skin glazed facades – Image or a step towards a sustainable society? Arkus (The forum of research and development of the architects), Stockholm, 2001 (in Swedish)

[2] Carlsson, P.-O.: Glazed facades – double skin facades. Arkus, Stockholm, 2003 (in Swedish)

Nr.	Country	Partner	Long Version			
			name	city	orientation	utilisation
1	Austria	IWT	BiSoP	Baden	S / N	school
2			Felbermayr	Salzburg	S	office - n.p.
3			Fachhochschule	Kufstein	NW	school / office - n.p.
4			Justizzentrum	Leoben	SE	office - p.
5			Schubertstrasse	Graz	SE	office - n.p.
6	Belgium	BBRI	Aula Magna	Louvain-La-Neuve	SE	other
7			Sony	Zaventem	NE / SW	office - n.p.
8			UCB Center	Brussels	NE / SW	office - n.p.
9	France	LASH-DGCB	Cité	Lyon	NE	office - n.p.
10			EAL	Vaulx en Velin	NE	school
11			Thiers	Lyon	E	office - n.p.
12	Germany	IBP	Münchner Tor	Munich	N / S / E / W	office - n.p.
13			Geschäftsgeb. Süd 1+4	Munich	N / S / E / W	office - n.p.
14			Zentralbibliothek	Ulm	N / S / E / W	library
15	Greece	NKUA	A-A Holdings	Athens	E	office - n.p.
16			Alumil M5	Kilkis-Stavrochori	E	office - n.p.
17			AVAX	Athens	E	office - n.p.
18	Portugal	ISQ	CGD	Lisboa	S	office - n.p.
19			Atrium Saldanha	Lisboa	SW	office - n.p. / services
20			ES Viagens / expo 98	Lisboa	SE	office - n.p. / school / services
21			Palacio Sotto Mayor	Lisboa	SE	school / services
22			Torre Zen	Lisboa	S	office - n.p. / school / services
23	Sweden	WSP	ABB	Sollentuna/ Stockholm	W	office - n.p.
24			Arlanda	Stockholm	N / S / E / W	other (airport terminal)
25			Glashuset	Stockholm	S	office - p. / school
26			Kista	Kista / Sockholm	S / W	office - n.p.
27			Polishuset	Stockholm	S / W	office - n.p.

Fig. 36 Analysed buildings with DSF within Bestfaçade

6.3 DSF in different climatic regions of Europe

The following picture gives an overview about the location of researched DSF all over Europe.

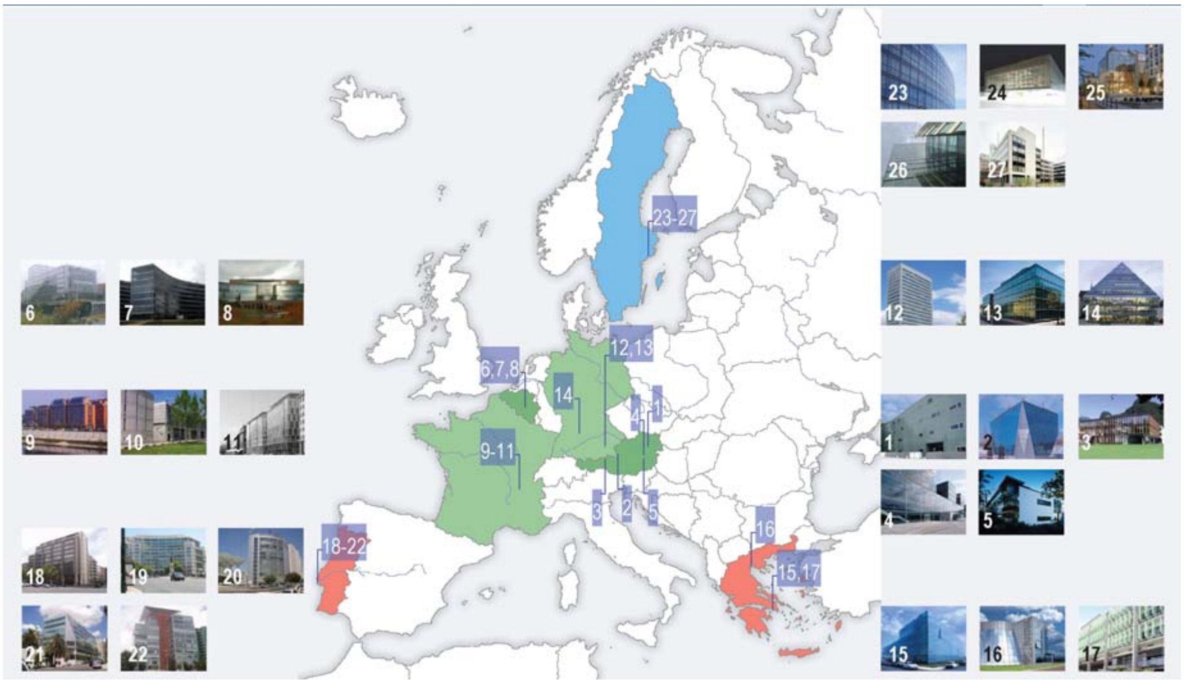

Fig. 37 Analysed buildings within Bestfaçade

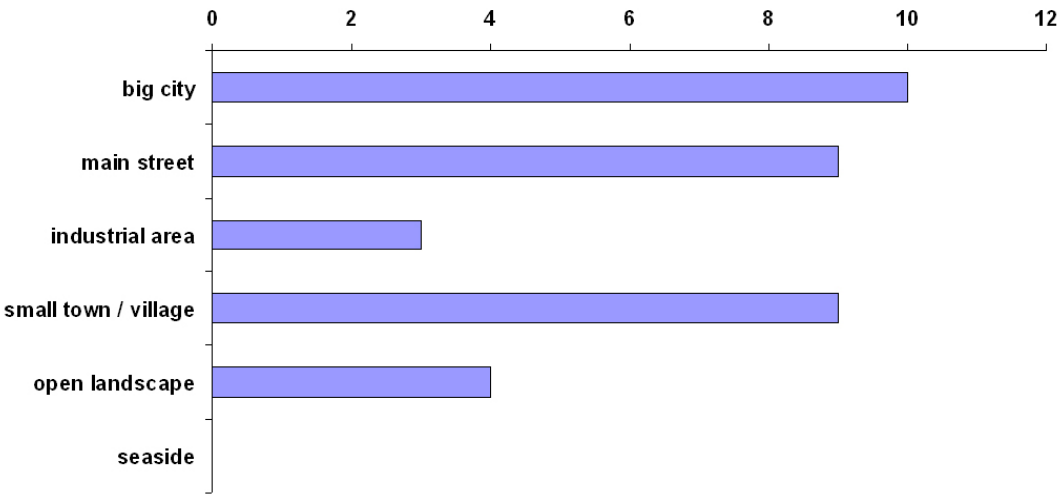

Fig. 38 Location of Bestfaçade buildings

As buildings with DSF are mostly erected in the bigger cities, which have a special "city-climate" nearly the same conditions apply for all the buildings per country. Though **Austria** covers different climates, thinking e.g. of the pannonian and the alpine climate, DSF concentrate in the capital town of Vienna. But in smaller towns there can be found DSF too - e.g. in Graz, Leoben, Salzburg and Bregenz. But those cities have similar climates too. Other countries like **Belgium** are too small to have distinctive regions. In some countries like **Sweden** and **Portugal** all researched buildings are situated in the capital town – so they have to be representative for their country. Therefore it is not easy to identify special types of DSF in a certain region of a country or one can say that this has no impact on the choice of the concept of DSF applied. However there are of course small differences concerning the solar radiation and temperature (e.g. in **Germany** with the Freiburg region and the Rhine area having more sunshine and higher temperature in summer than for example the regions near the North Sea).

To structure the results according to climatic circumstances three main regions covering the researched countries within Bestfaçade are proposed:

- "The Nordic Region" with it's only representative **Sweden**
- "The Moderate Region" with **Austria**, **Belgium**, **France** and **Germany**
- "The Mediterranean Region" with **Greece** and **Portugal**

The benchmarking system and the guideline will take into account those three regions and their special circumstances for their analysis.

For example **Greece** is located in the south-eastern part of Europe between the 34° and 42° parallel N., with a meridian extent from 19° to 28° E. The climate in Greece is typical of the Mediterranean climate: mild and rainy winters, relatively warm and dry summers and, generally, extended periods of sunshine throughout most of the year. The year can be subdivided into two main seasons:

- The cold and rainy period lasts from mid-October until the end of March. The coldest months are January and February, with, a mean minimum temperature of 5 -10 °C near the coasts and 0–5 °C over the mainland, and lower values over the northern part of the country.
- The warm and dry season lasts from April until September.

During this period the weather is usually stable, the sky is clear, the sun is bright and there is generally no rainfall. The warmest period occurs during the last ten days of July and the first ten days of August, with a mean maximum temperature of 29 – 35 °C

For the climate of Greece, control of solar gains in the building design is important during the summer periods. Therefore double skin facades may lead to overheating during the summer months if there is no appropriate façade design, ventilation technique building orientation and provision of shading.

The climate of Greece encourages the use of natural ventilation in office buildings. However, in the last decades, it is noted an increased use of air-conditioning due to high ambient air temperatures and high internal gains in large office buildings.

Many of the above mentioned potential advantages of office buildings with double skin facades are likely to be valid for **Sweden** as well. In addition there are other potential problems. The following potential problems are being studied for Swedish conditions[1] :

- Warm summer/spring/autumn days high temperatures in office rooms can occur as a result of window ventilation
- Low altitude of the sun, which result in fairly high cooling demands during spring and autumn
- Possible risk of high energy use
- Risk of low daylight levels in the central parts of the building, mainly for deep buildings
- High operating and maintenance costs

Many modern Swedish office buildings have large glazed facades. As mentioned above some of them have an additional façade i.e. double skin facades. The simplest and most common system solutions in Sweden entail that the façade is only ventilated to the outside. Most of the time this means that the office building behind has a traditional heating, cooling and ventilation system. Window ventilation is usually not possible, apart from French doors, which purpose is to gain access to the double skin façade cavity for maintenance.

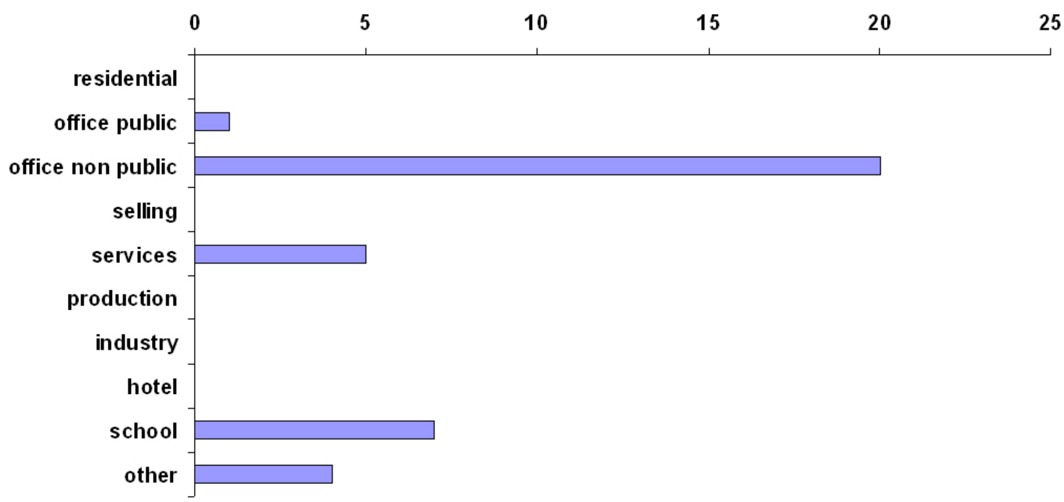

Fig. 39 Utilisation of Bestfaçade buildings

[1] Blomsterberg, Å.: Project description, Glazed office buildings – energy and indoor climate. www.ebd.lth, 2003

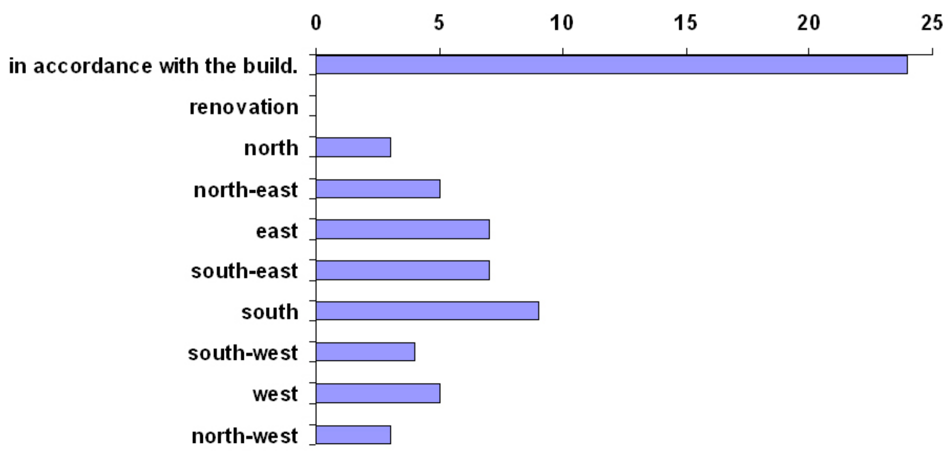

Fig. 40 Implementation and orientation of façades within Bestfaçade

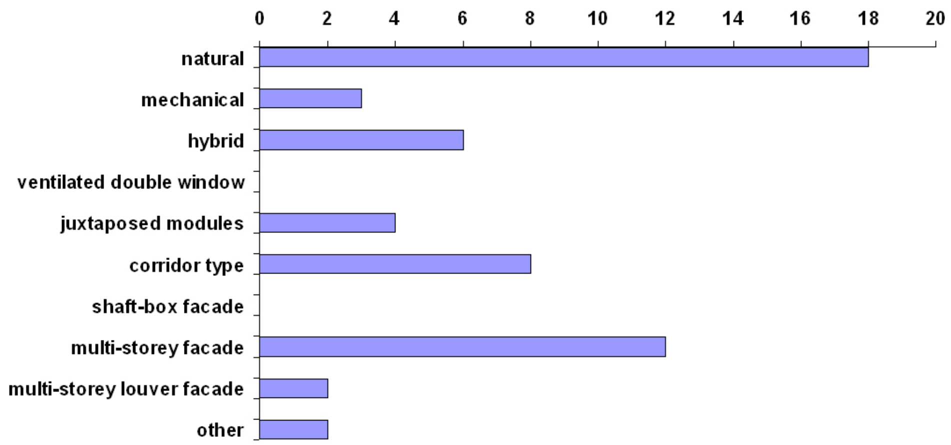

Fig. 41 Partitioning of the gap

6.4 Existing simulations and measurements

In **Austria** not many measurements have been done from which data is disposable. From BiSoP / Baden south façade intensive measurement data compared to simulation data is available. In this case the aim was to research the physical behaviour of the façade and not primarily their influence on the rooms behind. FH Kufstein has done some simulations and measurements as well. From Felbermayr / Salzburg some single measurement data is available while Uniqa has done much work on this but until now it hasn’t been possible to get those data.

In **Belgium** BBRI has carried out several measurements on DSF: some in situ, some in outdoor test cells and some in laboratory. Different fields were examined: energy, ventilation, acoustics and daylight. A detailed monitoring of the most common concept of DSF applied in Belgium has been performed during the year 2005 in order to determine the thermal and solar properties (in winter & summer) of this kind of façades. Some universities have also performed measurements in laboratory or in situ. All these measurements have been realised at the level of the façade component (and not at the level of the building). BBRI has also performed simulations on different kinds of DSF, also in different fields: energy, acoustics and daylight. In the design phase of a building equipped with a ventilated double facade, it is essential to be able to predict the energy performances of the facade in the building and this for different design possibilities of the facade. The possibility of modelling the facade (and the building) with simulation programs can play an important role from that point of view and allows to compare different possible design concepts.
The prediction of the energy performances of a ventilated double facade is a complex matter. The thermal process and the airflow process interact. These processes depend on the geometric, thermo-physical, optical and aerodynamic properties of the various components of the ventilated double facade.
BBRI has written a document, which explains how the thermal and solar performances of ventilated double facades and of buildings equipped with this kind of facades can be predicted by simulation. The control aspects are considered too. In some cases, measurements and simulations have been compared[1].

The objectives of this document were the following:

- to consider not only the modelling of the ventilated double facade alone, but also the modelling of the whole building equipped with the facade, the HVAC systems and the control aspects. Simulation programs (only software which are available on the market) are analysed. Studying the interaction between the facade, the building and the installations is important for a good assessment of the performances of ventilated double facades. Until now, practically no research study has assessed the impact of the control systems and the integration of ventilated double facade with the HVAC systems
- to analyse the capability to simulate control systems and control strategies
- to assess the various simulation programs on basis of their modelling possibilities, user-friendliness, advantages, disadvantages, etc.

[1] Flamant G., Heijmans N., Guiot E.: Ventilated double facades - Determination of the energy performances of ventilated double facades by the use of simulation integrating the control aspects – Modelling aspects and assessment of the applicability of several simulation software,. Belgian Building Research Institute (BBRI) - Department Building Physics, Indoor Climate and Building Services, December 2004

- to explain how a ventilated double facade can be modelled with the various software. Sometimes, 'tips' are needed. This is the reason why the knowledge of experts in simulation has been collected.

In **Germany** DSF are applied mostly at high-level office buildings. The building owner or user is normally not interested to publicise the planning information in detail. Technical journals like architectural journals often show high-quality photos of the facades and describe the usefulness of the façade with many words, but the simulation results and even more the measured energy consumptions or occurring temperatures are rarely presented. Additionally detailed measurements are mostly initiated after occurring problems with the indoor comfort or high energy consumptions. This leads partly to bad reputation of DSF between specialists in this field. It is necessary that good examples, that means buildings with DSF and low energy consumption as well as good indoor comfort have to be more documented, monitored in detail and publicised.

With simulations it has to be checked if the boundary conditions dependent on the user, the weather, the HVAC influence, etc. are represented in a correct way so that the reality after the erection of the building does not deviate too much from the simulated results.
The experience at Fraunhofer-IBP concerning DSF buildings, include the following buildings:

- Fraunhofer Central Administration, Munich (owner: Fraunhofer Gesellschaft, 2000, simulation)
- Neubau Katharinenhospital, Stuttgart (owner: city of Stuttgart, 2002, simulation)
- Neubau Bibliothek Ulm (owner: city of Ulm, 2003/2004, simulation, control strategy)
- Münchner Tor, München (owner: Münchner Rück, 2005, energy performance certificate)
- Sued 1, München (owner: Münchner Rück, 2005, energy performance certificate)
- Berlaymont Building, Brussels (owner: European Union, 2005, energy performance certificate)
- VERU test facility for entire building concepts (owner: Fraunhofer-IBP, 2004, measurements, performance assessment calculations)

The only known simulation in **Greece** was made for the new headquarters building (currently under construction) of ALUMIL S.A. in Kilkis in northern Greece, as part of an international architectural competition where the building got the 2nd prize in the professional category. This simulation focused on the comparison of the double skin façade being constructed to a typical single skin façade building, a base case building following the Greek building regulations and a typical brick building. This comparison was made on energy consumption, lighting needs in daytime, visual comfort, shading flexibility and the possibilities for views from the interior spaces of the buildings. On all accounts the proposed double skin façade was better than the buildings simulated, apart from the comparison on lighting needs during daytime, where the single skin building was better.

Measurements of the environmental performance of the existing Alumil DSF have been carried out by NKUA within the frames of the research programme 'BESTFACADE'. The measurements include:
Dry bulb temperature [°C] of external shell, façade gap and internal shell using a thermometer. Relative humidity [%] of external shell, façade gap and internal shell using a humidity sensor. Air change rates [ach] of the façade gap using a tracer gas system according to the decay method. Wind speeds [m/sec] externally and in the façade gap using a hot wire anemometer. Global solar radiation [W/m^2] perpendicular to the external shell, façade gap and internal shell using a pyranometer. Levels of day lighting [lux] externally, in the façade gap, internally and on task levels using a luxometer.

Additionally, the energy (electricity, air conditioning, heat pumps, lighting) and environmental performance (thermal comfort, temperatures and relative humidity) of the AVAX SA Headquarters office building has been monitored by an electronic digital system for central monitoring and control (BMS). The monitoring was carried out for the period 1/07/2000 to 30/06/2001.

Despite the interest that **Portuguese** architects show towards DSF technology, until recently this interest was not accompanied by the Portuguese scientific energy-related community. This situation was reversed recently (in 2005) with the inclusion of Portuguese research institutions in scientific projects related to the evaluation of DSF technology (e.g., Bestfaçade). Doctorate and Master students and researchers from ISQ, LNEC and INETI (Portuguese research institutions) are currently studying different aspects of Portuguese DSF buildings, both through the use of simulation tools (Energy-Plus and DOE-2), laboratory tests (air flow field details) and gap and indoor monitoring (acoustic, thermal, lighting and energy parameters). One DSF building is currently being thoroughly monitored and more than 5 scientific papers where submitted for presentation at international conferences. Recently, in the context of the design of a new DSF building to be located in the Expo98 area – Lisbon -, a prototype of a DSF as been build and monitored for thermal conditions in the air gap.

In **Sweden** simulations have been made of energy use and indoor climate of buildings with DSF, using multicell dynamic simulation tools. However, there is not yet any commercial simulation tool available, that actually simulates the DSF. The knowledge is insufficient on the actual energy performance, indoor climate performance etc. of the buildings with DSF. Partly due to the fact that most of these buildings have only been in operation for a couple of years.
In many projects with double skin facades simulations of temperatures, air and energy flows have been carried out before and during the design, with more or less success. Often the simulations have deviated from the result in the finished building. Often this depends upon difficulties in defining and accurately determine the boundary conditions. To succeed with calculations not only good experience of the used simulation models is required, but also good knowledge in thermodynamics, fluid dynamics and building physics, and general

shrewdness and experience of building services engineering. Increased knowledge concerning and improvement of simulation and calculation methods are needed.

6.5 Thermal behaviour, indoor air quality, comfort, user acceptance

The thermal comfort encountered in a building equipped with a DSF can be improved compared to a single glazed façade, especially during winter where the temperature of the inner glazing will be usually higher than for a traditional façade. That reduces the thermal radiation of the cold surface of the glazing.

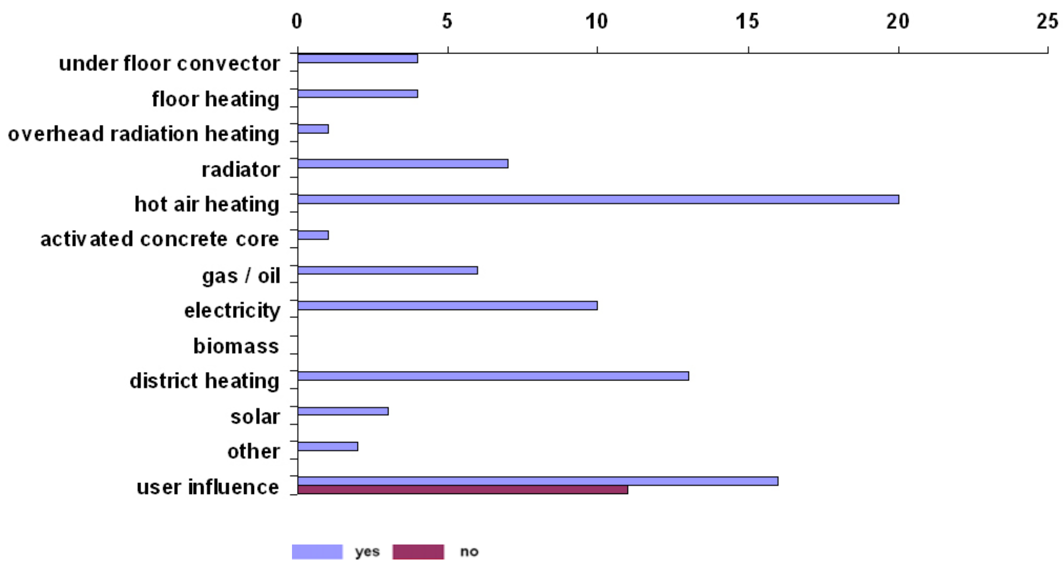

Fig. 42 Types of room heating devices and used energy source of Bestfaçade buildings

In summer, the air temperature in the cavity of the DSF can be high (>50°C), depending on the concept of DSF. The temperature of the inner glazing can reach in these cases high levels (>30°C), which can create a thermal discomfort and overheating (or higher energy consumption for cooling). A proper choice of the shading device and of the air ventilation rate is important.

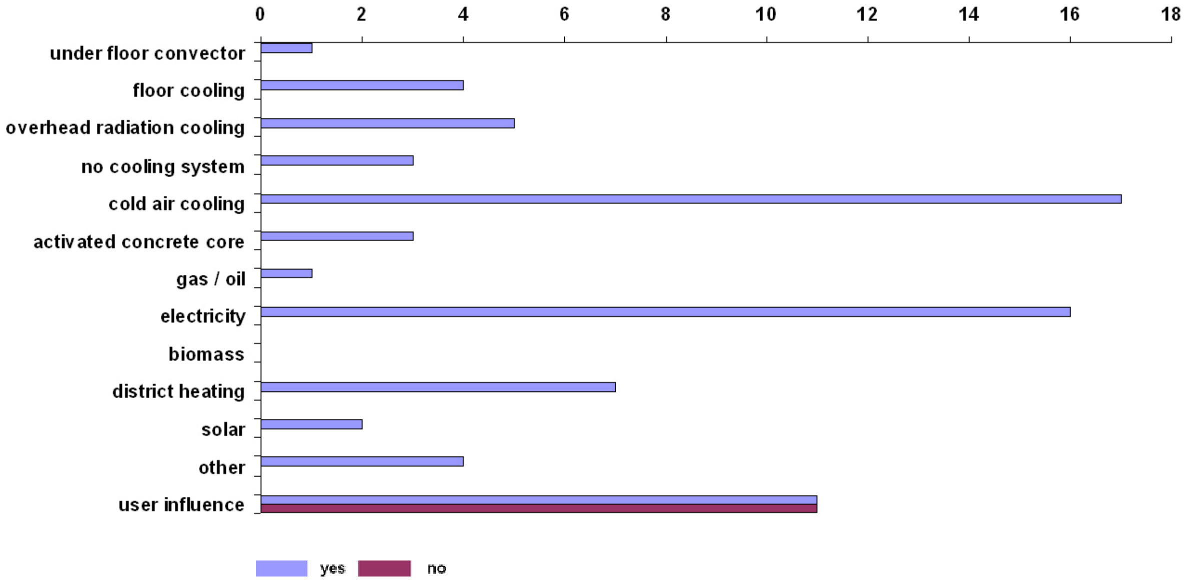

Fig. 43 Types of room cooling devices and used energy source of Bestfaçade buildings

For some encountered concepts of DSF in **Belgium**, there is no direct influence of the façade on the air quality in the adjacent room since the air of the room is extracted via the façade (no air supply).

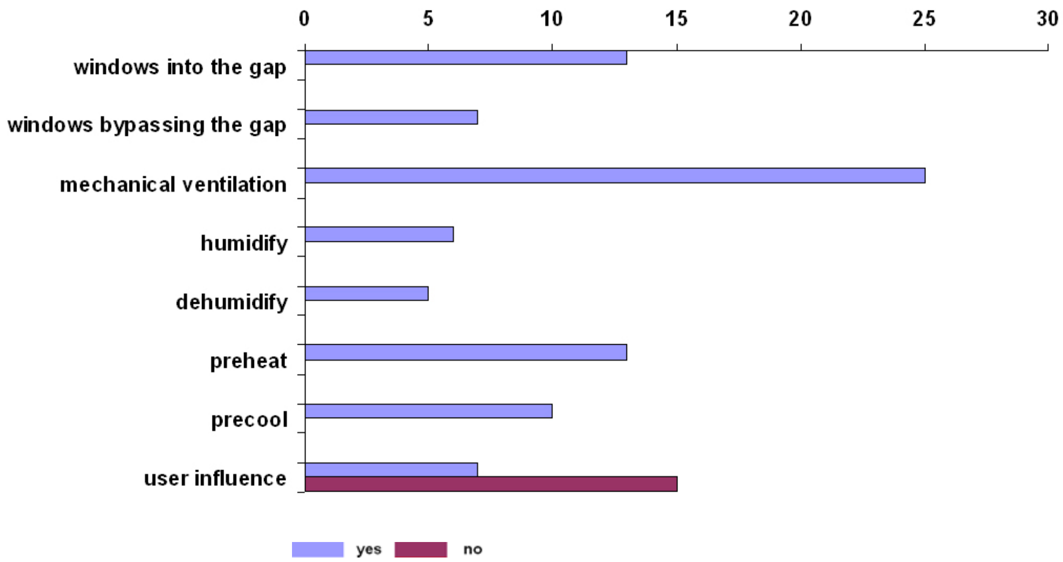

Fig. 44 Ventilation and air conitioning of Bestfaçade buildings

In some former published articles on **German** DSF buildings the applied technology leads to high temperature in the façade gap in summer that partly causes overheating problems in the adjacent rooms. This is mostly solved by big air-conditioning plants and therefore high operation costs. However some buildings and especially those buildings mentioned in detail in the attached building typology show that with considerate planning DSF do not necessarily lead to critical thermal situations and comfort problems. In any case the planning also in the region of Germany has to be based on the summer conditions. First the overheating problem has to be solved and secondly the façade should be adapted to possible gains during the winter. The indoor air quality may be influenced by the façade in several ways if there are openings from the rooms to the façade gap:

- positively, because in the high-tower office buildings a natural or hybrid ventilation might not be possible without the DSF
- positively if the air taken from the gap into the rooms in winter is warmer than the room temperature (possibility of reduction of the heating demand).
- negatively as the façade may lead to bad air quality being transferred from one room to the other (e.g. with smokers)
- negatively if the air taken from the gap into the rooms in summer is hotter than the room temperature (increase of cooling demand).

The user acceptance is dependent on these influences (thermal behaviour, indoor air quality and comfort) but also on the possibility to control his environment as well as other things like acoustics, aesthetics, etc.

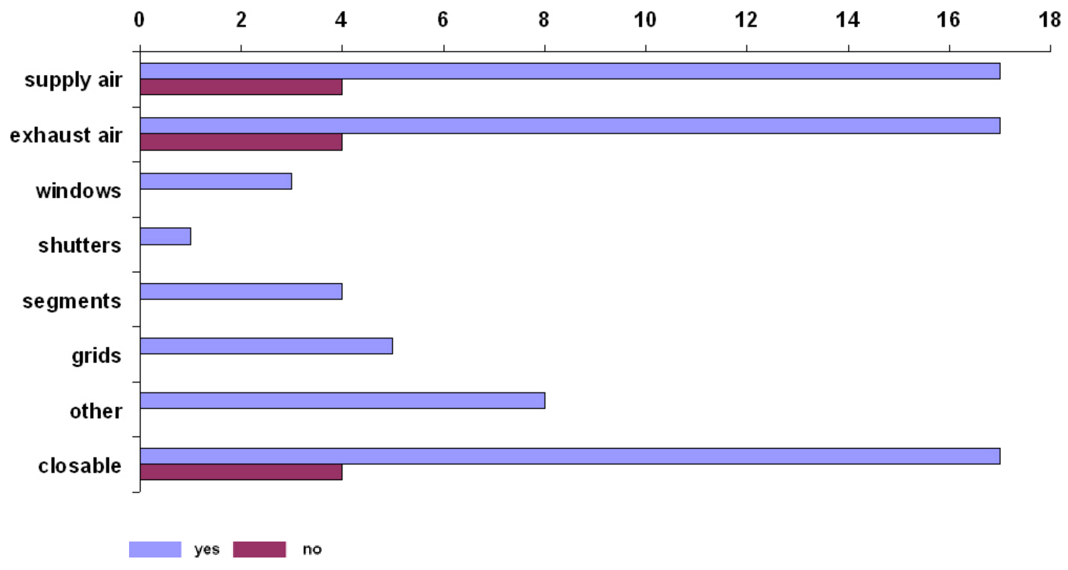

Fig. 45 Ventilation openings in outer shell of analysed façades

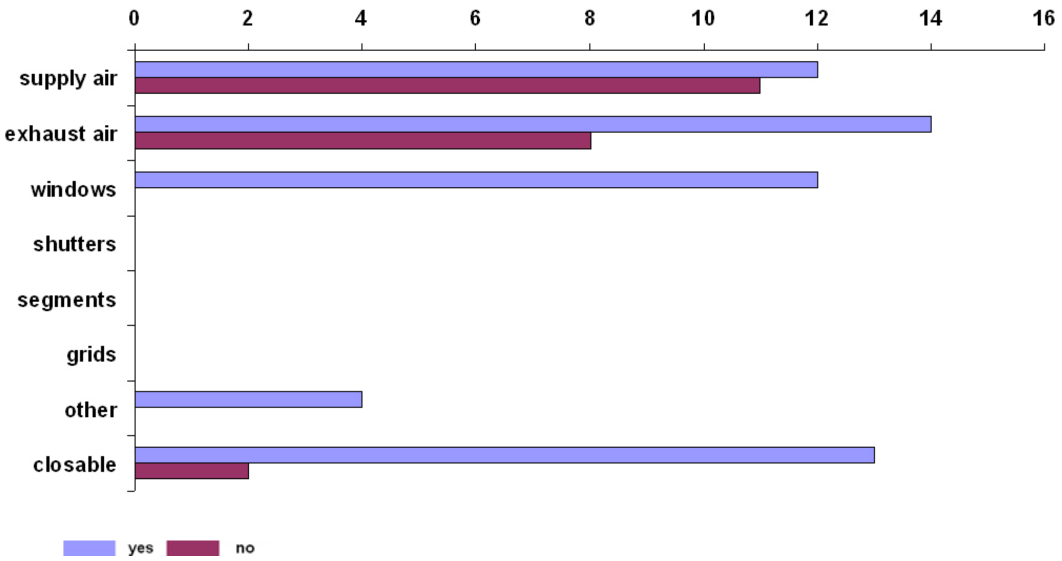

Fig. 46 Ventilation openings in inner shell

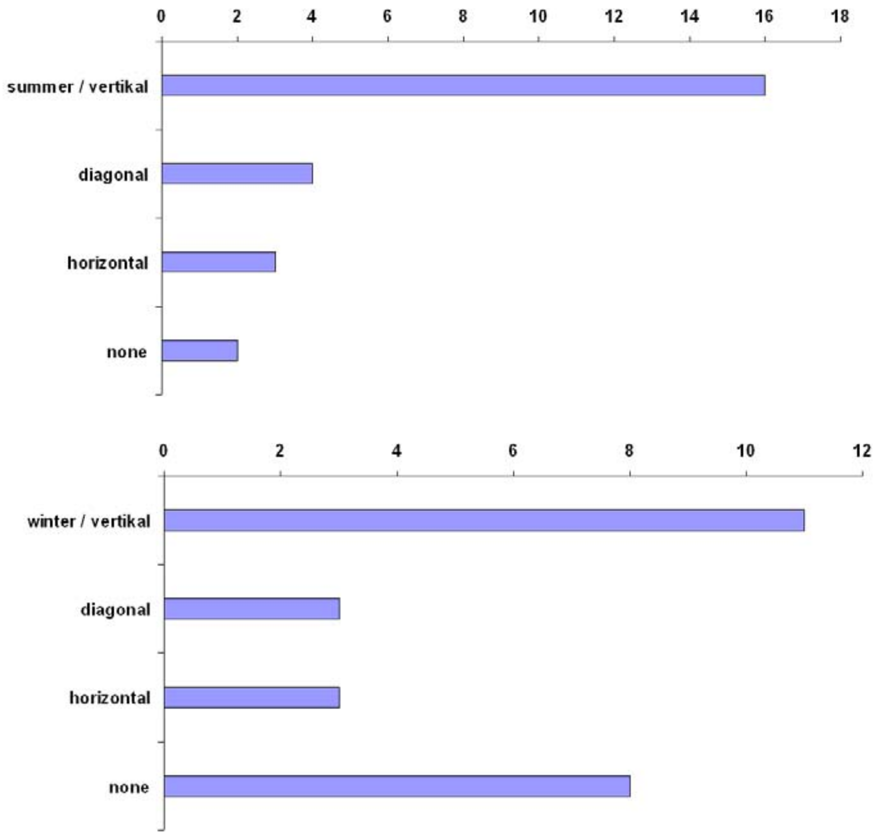

Fig. 47 Air flow in the gap in summer (above) and in winter (below)

The published results regarding the thermal behaviour, indoor air quality and comfort of DSF buildings in **Greece** apply to the AVAX Headquarters offices that were monitored via the Building Management System. Additionally, questionnaires on thermal comfort were distributed to the users. The results show that:

- Due to the design, orientation and building façade good visual comfort was achieved in the office areas provided mainly by natural day light
- Thermal comfort was mainly described as 'neutral' with little request to changes
- Energy consumption was reduced and almost half compared to similar buildings with conventional lighting and air-conditioning systems.

The users' acceptance to DSF is evaluated within the 'BESTFAÇADE' project. Currently DSF examples have no reputation in Greece because of their limited application. Initial results of the analysis show that the users are positive with the idea of the DSF systems if the façade design does not lead to overheating.

Due to the lack of scientific and field studies it is difficult to report on the thermal behaviour, indoor climate, comfort and user acceptance of DSF buildings in **Portugal**, and to conclude a better or poorer performance of DSF when compared to single-glazed façade. A preliminary analysis of some of the existing buildings (type of glazing, shading) suggests that problems of overheating could occur. Information gathered from conversations with architects, maintenance personnel also points to this possibility/reality. Studies currently ongoing in Portuguese DSF buildings (within the frame of Bestfaçade project, for example) will contribute to clarify these very important aspects.

As in all countries a comprehensive view because of the complexity of building and HVAC system is required . Energy, comfort and costs must be analysed. The long, cold and dark winters in **Sweden** can cause thermal comfort problems. The low altitudes of the sun can result in fairly high cooling demand during spring and autumn. The visual comfort can be problematic due to glare in the boundary zone. For deep buildings the daylight level can be low in the core of a building, although the façade is fully glazed.

Obviously there is an uncertainty in the building trade as to the design of buildings with highly glazed facades and how to calculate the use of energy, the comfort and the influence on these buildings of different technical solutions.

6.6 Energy demand and consumptions

There are very few data available on energy demand and consumptions of buildings equipped with DSF in **Belgium**. These data are not easy to get. Work performed in this Bestfaçade project (WP3) will provide some information.
D. Saelens, who worked in a Belgian university and who worked also in the framework of the national project on DSF managed by BBRI, wrote a PHD thesis about the determination of the energy performances of DSF and about the optimisation of these performances.

As mentioned above energy demands and consumptions are not easy to get for most German buildings too. There are publications showing very high energy consumptions in some well-known DSF-office towers in **Germany**. Two of the projects analysed within BESTFACADE include the comparison between the final energy demand calculated with DIN V 18599 according to the new EPBD (Energy Performance of Buildings Directive) requirements and the final energy consumption. In these cases both calculation of demands and monitoring of consumption by the energy provider result in values that are in the range of usual office buildings or better.

The published results regarding the energy consumption of DSF buildings in **Greece** refer to the AVAX SA Headquarter offices. The results, show that the façade design in conjunction with the use of natural ventilation, night mechanical cooling, and energy efficient lighting results in significant energy savings and operational costs.

The level of knowledge on double skin facades among most scientists, builders/developers, consulting engineers and architects in **Sweden** is fairly limited especially concerning the actual energy and indoor climate performance of the building behind the façade apart from some major property owners/developers, engineers and architects. A situation similar to this also happens in **Portugal**.

6.7 Control strategies

In **Belgium** the control systems and strategies have been studied during the national project on DSF managed by BBRI. This study has shown that the control systems and strategies applied in buildings equipped with DSF are, most of the time, very similar to these applied for single glazed building. An efficient working of the façade is only possible when the control of motorized components that are integrated in the DSF is efficient. This can be realised via the BMS (Building Management System), which allows a optimal working of the different systems of the building.

In Belgium the use of BMS systems is currently not yet generalised Very often, no major differences in the control strategy applied exist between a traditional building and a building equipped with DSF.

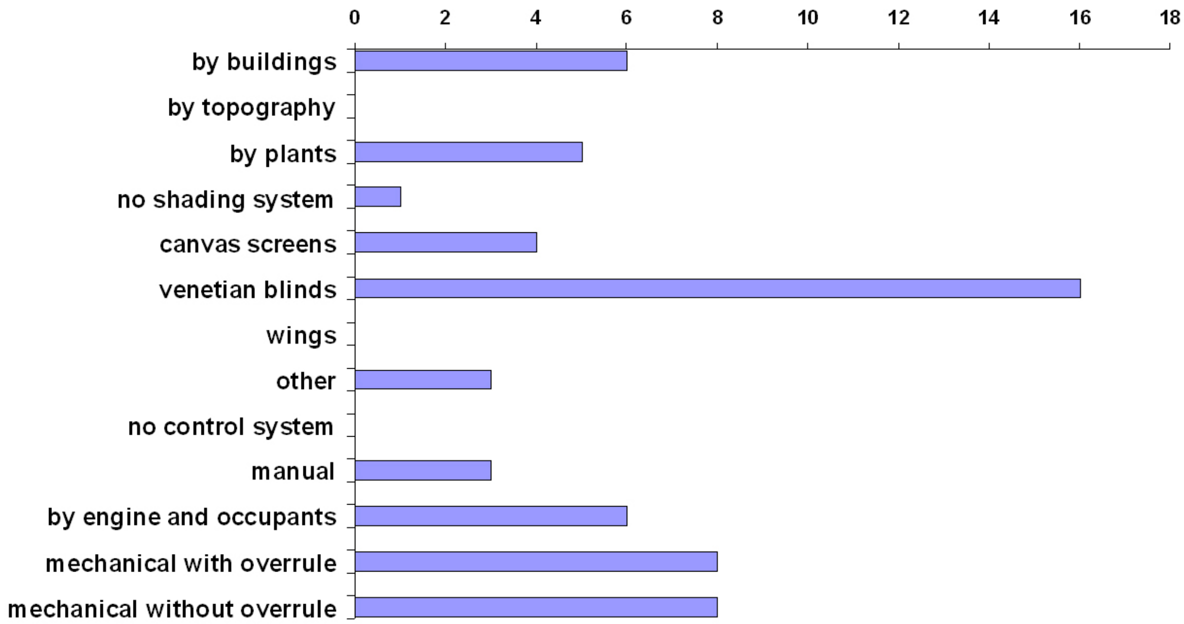

Fig. 48 Shading of analysed façades

Control strategies for the façade and/or the building and plants behind the façade are various and very dependent on the type of façade (self operating/passive up to actively influencing the climate in the building). The façade control may cover the following parts: openings of the façade (ventilation of the gap), support of the ventilation behind the outer façade, solar shading and day lighting.

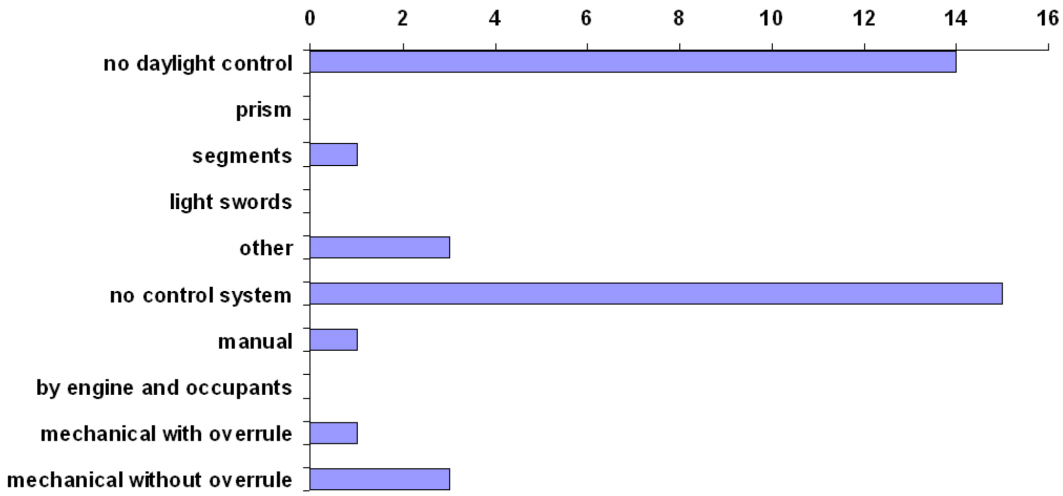

Fig. 49 Daylight control in analysed façades

The control strategy of the building that means mostly the heating/ventilation/cooling/lighting systems should be adapted / linked to the control of the façade (if there exists one) and to the user boundary conditions. In high-level office buildings the controls are mostly realised by the BEMS (Building Energy Management System), which can at the same time monitor the energy consumption of the building. By this it is easier to refine the control strategy towards the most suitable and energy efficient one and discover unnecessary energy consumption because of false control strategies or mistakes in the programming. A commissioning of the building and the plants is indispensable.

In **Portugal** the more recent DSF buildings include façade related control strategies, mainly for cooling and lighting systems. This control is made automatically through the Building Energy Management System.

6.8 Integrated building technology

In **Belgium** usually, for the big majority of buildings equipped with DSF, the whole concept including the façade as well as the HVAC system are similar. The façade is mechanically ventilated with cooling beams or cooling ceilings with activated concrete. The room air, which is extracted via the double façade, is returning via ventilation ducts to the HVAC system. The control of the shading device situated in the façade cavity can be done manually or centralised at the level of the room or at the level of the building via the BMS.

DSF allow to a special extent the integration of technical systems for the conditioning of the rooms. Local air-conditioning systems disburden the installation ducts in the building core.

With newer projects DSF developments have been realised that include besides the room conditioning also lighting systems and PV elements within the façade.

Integrated building technology exists in DSF buildings in **Portugal**. The oldest of this building, designed in the 1980, already included a system to recover the heated gap air and use it to heat offices located far from the double skin façade.

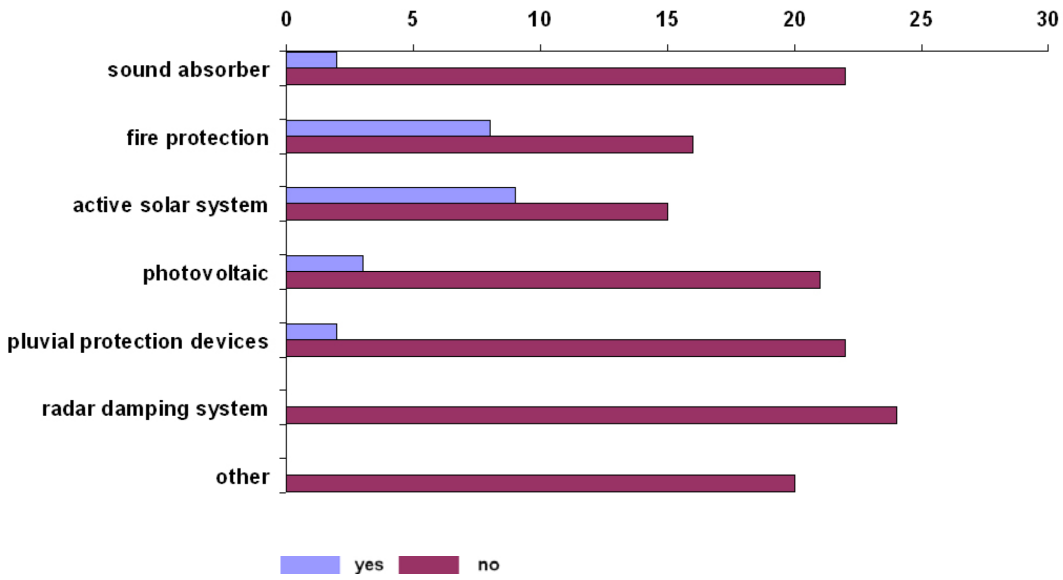

Fig. 50 Integration of different devices into the façades (besides shading systems)

6.9 Costs (investment, maintenance, operation)

In the national **Belgian** project on DSF, BBRI has not carried out a very detailed analysis of the costs of the buildings equipped with DSF. Nevertheless the different elements having an impact on the cost of DSF were analysed.
The initial investment of the DSF constitutes an extra cost that can be very high for some specific concepts of DSF. For the most common used DSF in Belgium (mechanical ventilated façade with juxtaposed modules), total cost ranges from 500 to 700 EUR/m² including solar shading is mentioned. With some concepts of DSF, heating appliances can be avoided, which reduces the installation costs, or the dimensioning of the heating appliances can be reduced. The impact of a DSF on the dimensioning and or the choice of the cooling systems depends on the solar performances (g-value) of the facade.

The operation costs are proportional to the energy (heating and cooling) reduction or increase for the whole building equipped with a DSF compared to a traditional building.

The maintenance costs specific to the glass skins is of course higher because of the presence of 4 surfaces to be cleaned. The source of the ventilation air passing through the cavity plays also a role: more cleaning is needed in case of a cavity ventilated with outside air. The environment (pollution / no pollution) also influences the frequency of cleaning. The shading device situated in the cavity of a DSF is protected against the wind and the rain, which is favourable compared to external shading devices.

As with the energy consumption the building owner and/or user in **Germany** do not aim at disseminating the costs for the erection of their buildings, with or without double skin facades. Construction management companies and façade manufacturers should have more insight into the investment costs. In case of the German project participant Fraunhofer Institute of Building Physics is mostly not part of the economical side of projects, but deals with energy-efficiency and energy economy. Anyway, a DSF means two façades (inner and outer shell, which doesn't necessarily have to add up to a price of two facades, but will lead to higher costs than most of the usual facades with only one skin. Additionally the DSF are mainly glazed on both shells, glazing and especially the necessary safety glass is more expensive than insulated panels.

The investment costs of the double skin façade applied at the VERU test facility amounted to 1255 €/m² façade area. It has to be mentioned that this façade has a very small total area of 40 m². The following graphics show costs that were collected from different publications on double skin facades.

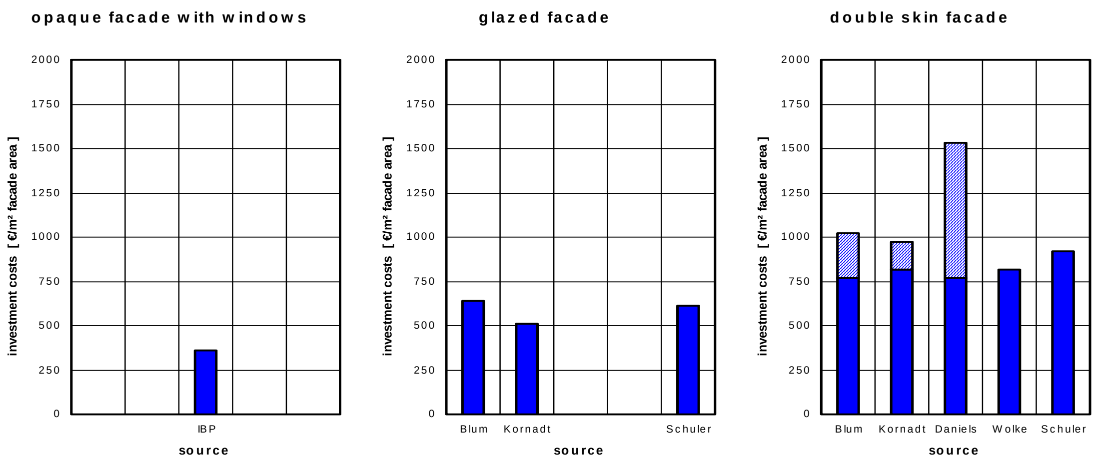

Fig. 51 Costs of DSF compared to conventional facades. The blue and white fields show the range of cost mentioned in the articles.

For Sweden very up to date estimated investment costs for the new WSP office building in Malmö are shown below. Builder/developer is Midroc Projects, costs according to WSP and

Schüco. Approximate investment costs for different glazed façade alternatives, €/(m² façade area):

- Single skin façade without exterior solar shading = 370,- €/m²
- Single skin façade with fixed exterior solar shading (catwalk is not included, simple control of solar shading included) = 580,- €/m²
- Single skin façade including daylight redirection (catwalk is not included, simple control of solar shading included) = 680 – 790 €/m²
- Double skin façade incl. Venetian blinds like Kista Science Tower = 920 – 1000 €/m²
- DSF box window type (cavity width 0,2 m) with Venetian blinds = 560 €/m²
- DSF box window type (cavity width 0,2 m) with Venetian blinds incl. daylight redirection = 610 €/m²

6.10 Ressource conservation and environmental impact

The environment impact of a DSF is influenced by two factors : the additional energy needed to build the DSF (i.e. the second glass skin compared to a single glazed façade) and the reduction/increase of the energy consumption of the building. Very few data are available on this.

The environmental impact can be described in two ways (energy consumption for the operation of the building and the used grey energy for the fabrication of the façade. Here again, two levels of façade will cause more grey energy than one level. Besides the glazing the DSF consists in most times mainly of aluminium frames. Aluminium is a material that consumes a lot of grey energy during the fabrication. However the manufacturers have searched for solutions to decrease in incorporated grey energy in their product and part of them are the production of aluminium in Norway (with hybrid power) and the high recycling rate of the material.

6.11 Comparison to conventional glass facades (CGFs)

The performance of DSF in **Austria** vary intensively: from buildings with good reputation like the Andromeda Tower / Vienna to facades which had severe problems e.g. with fallen down glass panes in Vienna (new buildings as well as retrofitted). On the other hand there are bad energy performing conventional glass facades (CGFs) too. In some cases DSF can be a good choice for retrofitting of buildings from the sixties and seventies. Advantages may be the good storage capacity, new aesthetics and noise reduction.

Different criteria play a role in the comparison between a DSF and a conventional façade. The evaluation depends on the concept of DSF.

- Energy consumption for heating: few data available. A detailed analysis must be performed in order to evaluate the possible energy savings. The DSF with juxtaposed modules is usually characterised by better thermal performances in winter than for a traditional façade.
- Energy consumption for cooling: few data are available. A detailed analysis must be performed in order to evaluate the possible energy savings. For the DSF with juxtaposed modules the cooling consumption can in some cases be higher than for a traditional façade equipped with external shading devices.
- Acoustics: the acoustical insulation (against external noise) of a DSF is better. But for, specific concepts of DSF, problems of indirect transmission of the sound through the cavity can occur (telephony effect).
- Daylight: good penetration of the daylight in the building equipped with DSF. This is also possible with single glazed facades.
- Fire: certain concepts of DFV can be a problem concerning the fire propagation. The second skin does not allow the evacuation of the smokes.
- Shading device : the DSF allows the utilisation of the shading device in all weather conditions due to the protection of the shading device situated in the façade cavity
- Opening of the window : possible with certain concepts of DSF to allow the natural ventilation of offices, even for high buildings
- High-tech image plays a role in the application of DSF.

The chapters above contain parts of the comparison with conventional facades divided into the specific items. It has to be mentioned that DSF may offer possibilities that can't be realised with most conventional facades e.g. natural or hybrid ventilation in high-rise buildings, etc.

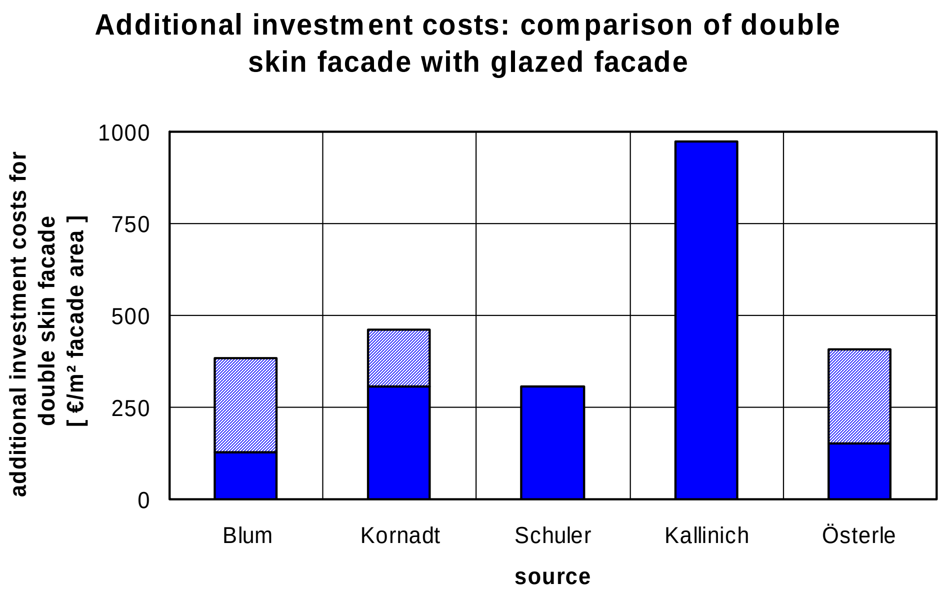

Fig. 52 Costs of DSF according to different authors. The blue and white fields show the range of cost mentioned in the articles.

The maintenance of the façade consists of cleaning and repair. The cleaning has now to be done at four levels (instead of two): inner and outer side of the external façade and inner and outer side of the internal façade. In wide double skin facades (>60cm), for the two middle levels most of the time accessible grids are part of the façade gap. This facilitates the work and leaves only the same levels as with conventional facades. However additional cleaning costs have to be taken into account with DSF. Also for repair two shells might now have defects. On the other hand a DSF offers some advantages like a protected shading system in the gap, which will less often have defects.

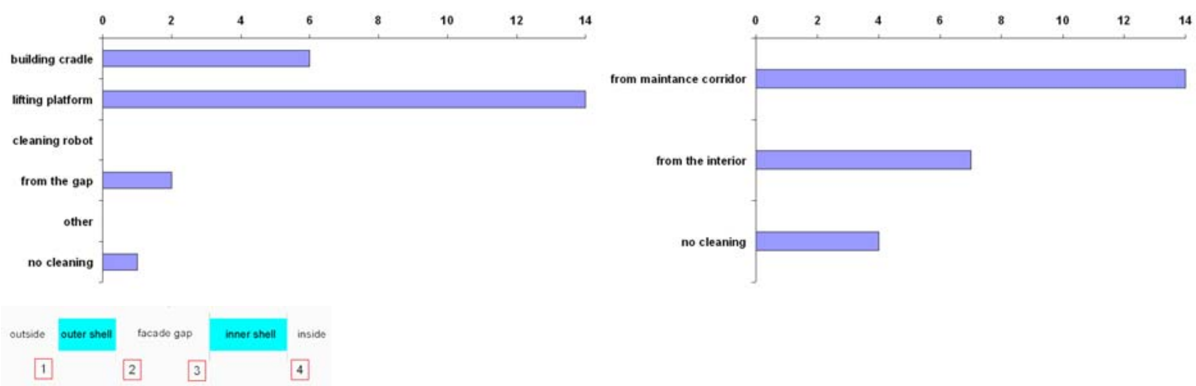

Fig. 53 How cleaning of surface 1 and 2 is done

The operation costs (= energy costs + maintenance costs) can't be entirely assigned to the façade system but on the building as a whole. As mentioned above the energy consumption of the building can be negatively influenced by bad planning of the DSF, kept at the same level and also slightly positively influenced by the DSF. Accordingly the energy consumption costs will increase, stay the same or decrease.

Double skin facades are more expensive than conventional facades. However, exact figures regarding the cost of DSF do not yet exist in **Greece**.

Considering the significant number of DSF buildings in Lisbon, the double skin façade technology has certainly acceptance among **Portuguese** architects and promoters. The combination of the aesthetical appearance that this technology enables and its "environmental attributes", often mentioned in Northern and Central European specialized literature, can be one of the main reasons for its use instead of single glazed façades.

6.12 Integration of renewable energy sources into DSF

The only case known among the researched **Austrian** DSF is the use of the concrete areas behind the south glass façade as solar collectors in BiSoP / Baden which should supply hot water radiators in the north façade to reduce temperature spread.

For **Belgium**, **Greece** and **Portugal** no applications are known.

Some DSF include photovoltaic implementations. The gained electrical energy can either be fed into the grid (in Germany with high subsidised prices) or used in the building itself. Wind energy, and solar thermal can not easily be linked with DSF, but of course can be an additional feature of the building. Other renewable energies like heat pumps, use of geothermal energy, wood or similar renewable fuels can be integrated into the building concepts, partly also for pre-heating/pre-cooling of the air of the building and maybe also inside the gap but are not specifically coupled to the DSF concept.

6.13 Non-energy related issues: acoustics, aesthetics, fire protection, moisture, corrosion, durability, maintenance, repair

Those issues may even be more important for user acceptance than energy related ones since the energy consumption is mostly not directly experienced by the occupants.

Acoustics can be one of the main reasons to apply DSF - e.g. with traffic noise (control room of the fire brigade / Graz, Schubertstraße). In many cases DSF by having an additional shell in fact reduce sound transmission from the outside. On the other hand depending on the type of DSF problems of noise transmission from room to room by the gap is reported. This can be reduced by choosing the appropriate partitioning system or by the implementation of acoustical absorbers in the gap.

Aesthetics are often the main aspect why to apply DSF. They give depth and sort of "crystal image" to the façade.

Fire protection is a serious item with DSF. Fire brigades have to destroy two shells to be able to help the building users in case of fire, also the flashover of a fire from one storey to the next can be facilitated by DSF depending on the partitioning system. The façade manufacturers have found solutions for the second problem and in case of facades where the gap is separated between the storeys the problem is smaller than in conventional facades. Some types of DSF such as "multi storey DSF" must not be applied to high buildings.

Depending on the ventilation concept sometimes problems with condensation are reported when warm and wet exhaust air is ventilated into the gap and meets the cold inner surface of the outer glass pane (e.g. FH Kufstein)

Durability - Due to the fact that DSF sometimes even nowadays are sort of prototypes difficulties have been reported with unproved durability - especially with pane fixtures (those problems may refer to CGFs too) and mechanically driven shutters or lamellae. Since DSF are a rather new development there has been no scientific in-situ long-term analysis of a bigger group of facades. On the other hand problems with the durability of examples of the façade type are not known.
The maintenance of the façade consists of cleaning and repair. The cleaning for double glazed facades has now to be done at four levels (instead of two): inner and outer side of the external façade and inner and outer side of the internal façade. For the two middle levels most of the time accessible grids are part of the façade gap. This facilitates the work and leaves only the same levels as with conventional facades. However additional cleaning costs have to be taken into account with DSF. Also for repair two shells might now have defects. On the other hand a DSF offers some advantages like a protected shading system in the gap, which will less often have defects. So all in all it depends on the amount of facade fixtures whether the need for maintenance is higher or not compared to CGFs.

7 Summary

WP1 was proposed as a starting point for the following work packages. Thus all partners have been involved into the design of the questionnaires according to the special needs of their work packages and have used their good contacts within the building scene to get data on implemented facades in their countries.

The architectural aspects of DSF in Europe are discussed for their conception and glass architecture in general, the need of an integrated planning approach, lighting, the multitude of the city, environmental architecture, the facade as communication and sound attenuation.

A centralised database containing literature about double skin facades has been created in the framework of the Work Package 1 serving as the knowledge base for further work in the Bestfaçade work packages such as non technological barriers, benchmarks, calculation method up to the dissemination activities. After a first round in WP1 more than 360 articles, books, proceedings, diploma thesis and PhD thesis about double skin facades are available within the literature database. A second upgrading of the literature database is planned for the last year of the Bestfaçade project. A special four-language keyword list (English, French, Dutch and German) was developed to classify the literature by reducing and completing an existing list from BBRI. This keyword list is the main feature for finding and using the literature database.

The documents are sorted and evaluated by their authors, keywords, language and publication type, with the objective to make it as easy as possible to find a special document or documents about a special aspect of double skin facades. The main function and advantage of this database is the possibility to get an efficient overview about the literature, ranked by keywords and their relevance in this document.
The second important part of the literature database are the full-text files behind the literature database entries. In the moment there are in summary 161 articles in form of PDF-files available. The PDFs can be searched also by keywords.

The main goal of WP1 was to analyse implemented DSF all over Europe. 27 facades of different buildings in all partner countries of Bestfacade have been studied by means of a standardized questionnaire. The questionnaire comprises data on location, information about the building and the facade, construction and route of air flow in the façade as well as maintenance and costs.

The analysis is been drawn for the aspects, types of façade in different countries, DSF in different climatic regions of Europe, existing simulations and measurements, thermal behaviour, indoor air quality, comfort, user acceptance, energy demand and consumptions, control strategies, integrated building technology, costs (investment, maintenance, operation), resource conservation, environmental impact, comparison to conventional glass facades (CGFs), integration of renewable energy sources into DSF, and non-energy related issues: acoustics, aesthetics, fire protection, moisture, corrosion, durability, maintenance, repair.

Most of the buildings are office buildings followed by schools and service buildings. Nearly all of the buildings have mechanical ventilation systems and the heating and cooling is performed most often by air heating/cooling systems. The types of façades are mainly multi-storey and corridor type, in Belgium juxtaposed modules are frequently used. The façade gaps are mostly naturally ventilated (except for Belgium, where the indoor air is led by mechanical ventilation via the gap to the centralized air handling unit). The shading is performed mainly with Venetian blinds located in the gap. The cleaning of the outer shell is done via a cradle or a lifting platform, the glazing of the gap is mainly cleaned from the gap or from the interior.

Unfortunately not so much measured date of energy demand and temperatures in the gap and the rooms behind are available, because building managers are not easily willing to give away such sensible data. In the course of the following work packages (especially WP3 and WP4) there will be additional effort put into this question.

8 Table of figures

Appendix

A 1 Overview of analysed buildings

01_ austria

address	
country	Austria
city	Baden bei Wien
postcode	A- 2500
street	Elisabethstraße
house number	14 -16

'Multi-storey' facade:
width of facade: 53,7 m - height of facade: 17,0 m

general	
identification of building	Bundesinstitut für Sozialpädagogik
year the design process started	ND
year of completion of building	1998
height of the building above ground level	17 m
width of the building (diameter)	14 m
length of the building (diameter)	53,7 m
total gross storey area	ND m²

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02_ austria

address	
country	Austria
city	Salzburg
postcode	A - 5020
street	Vogelweiderstraße
house number	115

'Multi-storey' facade:
width of facade: 18,5 m - height of facade: 12,0 m

general	
identification of building	Bürohaus Felbermayr Salzburg
year the design process started	2002
year of completion of building	2004
height of the building above ground level	14 m
width of the building (diameter)	13 m
length of the building (diameter)	25 m
total gross storey area	227m²

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03_ austria

BEST FACADE

address	
country	Austria
city	Kufstein
postcode	A- 6330
street	Andreas-Hofer-Str.
house number	7

???
width of facade: 39,7 m - height of facade: 11,0 m

general	
identification of building	Academy of appl. sciences Kufstein
year the design process started	ND
year of completion of building	2001
height of the building above ground level	11 m
width of the building (diameter)	39 m
length of the building (diameter)	55,8 m
total gross storey area	7800 m²

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04_ austria

BEST FACADE

address	
country	Austria
city	Leoben
postcode	A 8700
street	Dr. Hanns-Groß-Straße
house number	9

'Multi-storey louver' facade:
width of facade: 21,5 m - height of facade: 17,5 m

general	
identification of building	Justizzentrum Leoben
year the design process started	2001
year of completion of building	2004
height of the building above ground level	21 m
width of the building (diameter)	30 m
length of the building (diameter)	96 (104) m
total gross storey area	13139 m²

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05_austria

address	
country	Austria
city	Graz
postcode	A- 8010
street	Schubertstraße
house number	39

Facade partitioned per storey - corridor type
width of facade: 30,7 m - height of facade: 6,8 m

general	
identification of building	Bürohaus Schubertstrasse
year the design process started	2000
year of completion of building	2003
height of the building above ground level	7 m
width of the building (diameter)	14 m
length of the building (diameter)	30,7 m
total gross storey area	4151 m²

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06_ belgium

address	
country	Belgium
city	Louvain-La-Neuve
postcode	B-1348
street	Grand Place
house number	

'Multi-storey' facade:
width of facade: 72,0 m - height of facade: 19,0 m

general	
identification of building	Aula Magna
year the design process started	1996
year of completion of building	2001
height of the building above ground level	19 m
width of the building (diameter)	72 m
length of the building (diameter)	31,5 m
total gross storey area	10694 m²

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07_ belgium

address	
country	Belgium
city	Zaventem
postcode	B-1930
street	Da Vincilaan
house number	Building D

Facade partitioned per storey with juxtaposed modules:
width of facade: 65,0 m - height of facade: 30,0 m

general	
identification of building	SONY
year the design process started	1999
year of completion of building	2003
height of the building above ground level	30 m
width of the building (diameter)	9 m
length of the building (diameter)	65 m
total gross storey area	11818 m²

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08_ belgium

address	
country	Belgium
city	Brussels
postcode	B-1070
street	Allée de la Recherche
house number	60

Facade partitioned per storey with juxtaposed modules:
width of facade: 117,0 m - height of facade: 14,0 m

general	
identification of building	UCB Centre
year the design process started	1995
year of completion of building	1998
height of the building above ground level	14 m
width of the building (diameter)	9 m
length of the building (diameter)	117 m
total gross storey area	9642 m²

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09_ france

address	
country	France
city	Lyon
postcode	69006
street	Quai CH.De Gaulle
house number	

Facade partitioned per storey - corridor type:
width of facade: ? m - height of facade: ? m

general	
identification of building	Cité Internationale
year of completion of building	1995
height of the building above ground level	17
width of the building (diameter)	14,00
length of the building (diameter)	53,70
total gross storey area	ND

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10_ france

address	
country	France
city	Vaulx en Velin
postcode	69518
street	Audin
house number	

Facade partitioned per storey - corridor type:
width of facade: 119,0 m - height of facade: 12,0 m

general	
identification of building	EAL, school of architecture of Lyon
year of completion of building	1987
height of the building above ground level	17 m
width of the building (diameter)	14 m
length of the building (diameter)	53,7 m
total gross storey area	ND

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11_ france

address	
country	France
city	Lyon
postcode	69003
street	
house number	

‘Multi-storey’ facade:
width of facade: 66,0 m - height of facade: 19,0 m

general	
identification of building	Immeuble Thiers
year of completion of building	2001
height of the building above ground level	17 m
width of the building (diameter)	14 m
length of the building (diameter)	53,7 m
total gross storey area	ND

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12_ germany

address	
country	Germany
city	Munich
postcode	D - 80805
street	Schlüterstraße
house number	6 - 10

Facade partitioned per storey with juxtaposed modules:
width of facade: 46,84 m - height of facade: 75,76 m

general	
identification of building	Münchner Tor
year the design process started	ND
year of completion of building	2004
height of the building above ground level	88 m
width of the building (diameter)	22,54 m
length of the building (diameter)	46,84 m
total gross storey area	55000 m²

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13_ germany

address	
country	Germany
city	Munich
postcode	D - 80805
street	Gedonstraße
house number	10/12

Facade partitioned per storey - corridor type:
width of facade: 43,99 m - height of facade: 18,00 m

general	
identification of building	Geschäftsgebäude Süd 1+4
year the design process started	1998
year of completion of building	2002
height of the building above ground level	23,47 m
width of the building (diameter)	45,2 m
length of the building (diameter)	80,82 m
total gross storey area	20705 m²

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14_ germany

address	
country	Germany
city	Ulm
postcode	89073
street	Vestgasse
house number	1

'Multi-storey' facade:
width of facade: 31,35 m - height of facade: 29,58 m

general	
identification of building	Zentralbibliothek Ulm
year the design process started	ND
year of completion of building	2004
height of the building above ground level	36,28 m
width of the building (diameter)	31,35 m
length of the building (diameter)	31,35 m
total gross storey area	6670 m²

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15_ greece

address

country	Greece
city	Athens
postcode	
street	Kifissos Avenue
house number	92

Facade partitioned per storey - corridor type:
width of facade: 146,0 m - height of facade: 16,5 m

general

identification of building	A-A holdings office building
year the design process started	ND
year of completion of building	2003
height of the building above ground level	16 m
width of the building (diameter)	16 m
length of the building (diameter)	146 m
total gross storey area	10198 m²

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16_ greece

address

country	Greece
city	Kilkis-Stavrochori
postcode	61100
street	Kilkis Industrial Area
house number	14 -16

'Multi-storey' facade:
width of facade: 40,0 m - height of facade: 12,0 m

general

identification of building	Alumil Head Office
year the design process started	ND
year of completion of building	1996
height of the building above ground level	12 m
width of the building (diameter)	10 m
length of the building (diameter)	46 m
total gross storey area	420 m²

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17_ greece

address	
country	Greece
city	Athens
postcode	11471
street	Koniari
house number	15

'Multi-storey louver' facade:
width of facade: 41,0 m - height of facade: 10,0 m

general	
identification of building	AVAX S.A. Headquarters
year the design process started	ND
year of completion of building	1998
height of the building above ground level	19 m
width of the building (diameter)	11 m
length of the building (diameter)	41 m
total gross storey area	3050 m²

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18_ portugal

address	
country	Portugal
city	Lisboa
postcode	1050-186
street	Av. Da República
house number	35

general	
identification of building	Caixa Geral dos Depósitos-Av.
year the design process started	1983
year of completion of building	1987
height of the building above ground level	41m
width of the building (diameter)	16 m
length of the building (diameter)	56,73 m
total gross storey area	7227 m²

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19_ portugal

BESTFACADE

address	
country	Portugal
city	Lisbon
postcode	1990 - 083 Lisbon
street	Av. Fontes Pereira de Melo
house number	Parcela 1.16.01

Facade partitioned per storey - corridor type:
width of facade: ? m - height of facade: ? m

general	
identification of building	Atrium Saldanha
year the design process started	
year of completion of building	1997
height of the building above ground level	52 m
width of the building (diameter)	?
length of the building (diameter)	?
total gross storey area	?

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20_ portugal

BESTFACADE

address	
country	Portugal
city	Lisbon
postcode	1990 - 083 Lisbon
street	Parque das Nações, Av. D. João II
house number	Parcela 1.16.01

Facade partitioned per storey - corridor type:
width of facade: 11,5 m - height of facade: 43,72 m

general	
name (identification) of building	Portugal Telecom - Expo 98 Building
year of completion of building	1998
height of the building above ground level	64 m
width of the building (diameter)	?
length of the building (diameter)	?
total gross storey area	8411 m
total gross storey area	67500 m²

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21_ portugal

address	
country	Portugal
city	Lisboa
postcode	1050-121
street	Av. fontes Pereira de Melo
house number	16

The facade gap is not structured:
width of facade: ? m - height of facade: 19,32 m

general	
identification of building	Palácio Sotto Mayor
year the design process started	
year of completion of building	2003
height of the building above ground level	25 m
width of the building (diameter)	25 m
length of the building (diameter)	59 m
total gross storey area	8189 m²

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22_ portugal

address	
country	Portugal
city	Lisboa
postcode	1990 - 083
street	Av. D. João II
house number	Lote 1.16.05

Box-box facade:
width of facade: ? m - height of facade: 43,5 m

general	
identification of building	Zen Tower
year the design process started	
year of completion of building	2003
height of the building above ground level	43 m
width of the building (diameter)	16 m
length of the building (diameter)	23 m
total gross storey area	14400 m²

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23_ sweden

address	
country	Sweden
city	Sollentuna (suburb of Stockholm)
postcode	191 62
street	Norra Malmvägen
house number	141B-143

'Multi-storey' facade:
width of facade: 160,0 m - height of facade: 20,0 m

general	
identification of building	ABB Business Center
year the design process started	ND
year of completion of building	2002
height of the building above ground level	24 m
width of the building (diameter)	25 m
length of the building (diameter)	160 m
total gross storey area	ND

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24_ sweden

address	
country	Sweden
city	Stockholm-Arlanda
postcode	19045
street	Box 53
house number	

'Multi-storey' facade:
width of facade: 350,0 m - height of facade: 12,0 m

general	
identification of building	Arlanda terminal F
year the design process started	ND
year of completion of building	2001
height of the building above ground level	20 m
width of the building (diameter)	35 m
length of the building (diameter)	350 m
total gross storey area	67500 m²

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25_ sweden

address	
country	Sweden
city	Hammarby Sjöstad (Stockholm)
postcode	12066
street	Lugnets Allé
house number	39

'Multi-storey' facade:
width of facade: 10,0 m - height of facade: 12,0 m

general	
identification of building	Glashusett
year the design process started	ND
year of completion of building	2002
height of the building above ground level	12 m
width of the building (diameter)	10 m
length of the building (diameter)	10 m
total gross storey area	400 m²

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26_ sweden

address	
country	Sweden
city	Kista (suburb of Stockholm)
postcode	16451
street	Färögatan
house number	33

Facade partitioned per storey - corridor type:
width of facade: 26,0 m - height of facade: 128,0 m

general	
identification of building	Kista Science Tower
year the design process started	ND
year of completion of building	2003
height of the building above ground level	128 m
width of the building (diameter)	26 m
length of the building (diameter)	26 m
total gross storey area	22000 m²

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27_ sweden

address	
country	Sweden
city	Stockholm
postcode	112 29
street	Bergsgatan
house number	

‘Multi-storey’ facade:
width of facade: 83,0 m - height of facade: 14,0 m

general	
identification of building	Police headquarters
year the design process started	ND
year of completion of building	2004
height of the building above ground level	14 m
width of the building (diameter)	18 m
length of the building (diameter)	83 m
total gross storey area	30000 m²

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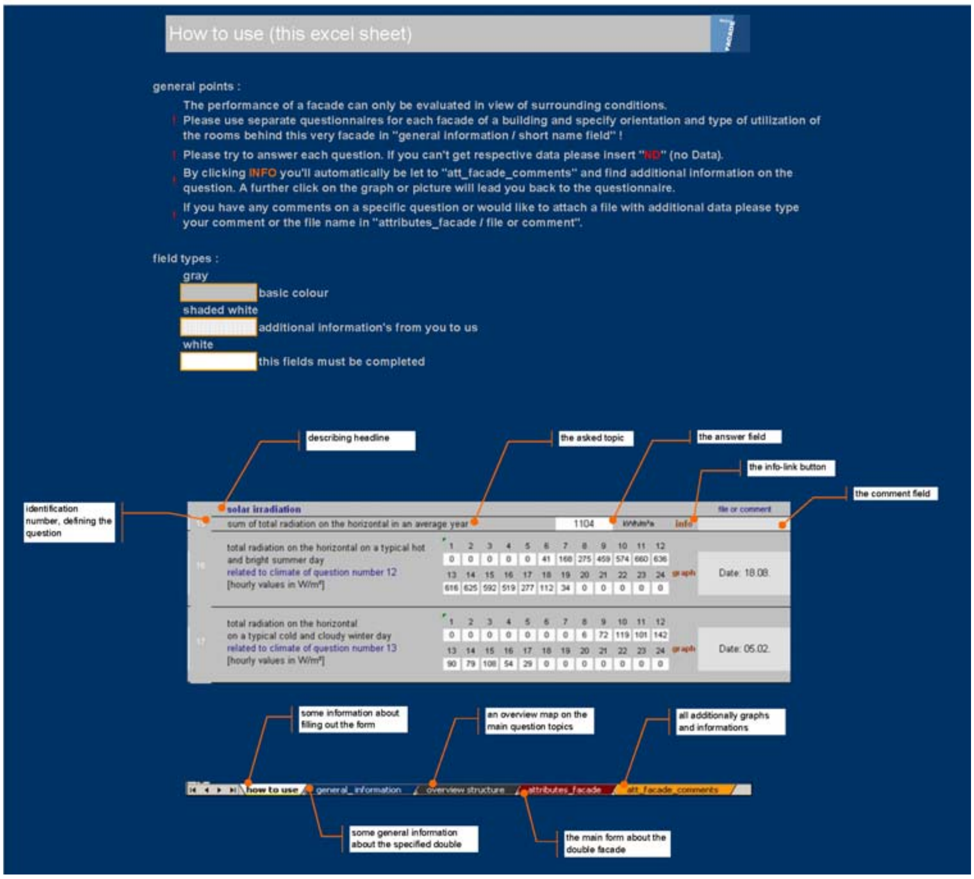
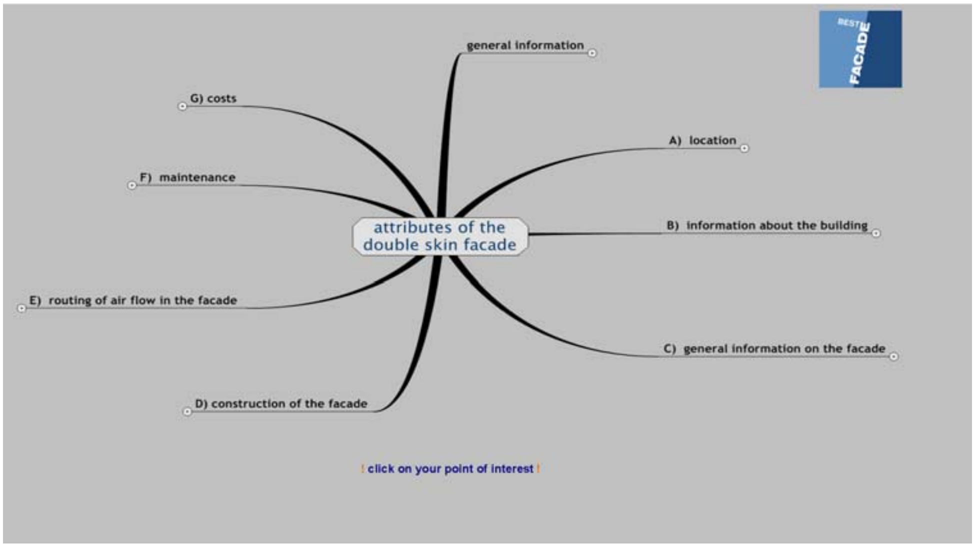
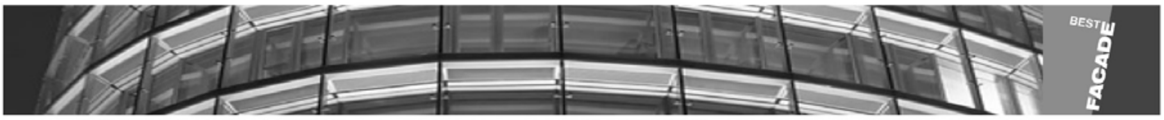
A 2 Long Version Questionnaire







attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

A location

info to structure

	address		**file or comment**
1	country (name in English)	Sweden	
2	city	Kista (suburb of Stockholm)	
3	postcode	16451	
4	street	Färögatan	
5	house number	33	

please insert a ground plan if available

6

	geographical position					**file or comment**
7	altitude above sea level	44	m			Weather station
8	latitude	59	degree	20	minutes	
9	longitude	18	degree	3	minutes	

climate data (on site measured data preferred)

info

	air temperature					**file or comment**
10	maximum in the last ten years		°C			
11	minimum in the last ten years		°C			
12	design heating temperature	-17	°C			
13	design day	26	°C	radiation	W/m²	

14 typical average monthly temperatures [°C] — graph — Stockholm 1971

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
-0,9	-1,4	-2,1	3,5	11,5	14,9	17,7	16,5	10,7	7,3	1,0	1,0

average annual temperature: 6,6 °C

15 typical hot and bright summer day [hourly values in °C] — graph

1	2	3	4	5	6	7	8	9	10	11	12

13	14	15	16	17	18	19	20	21	22	23	24

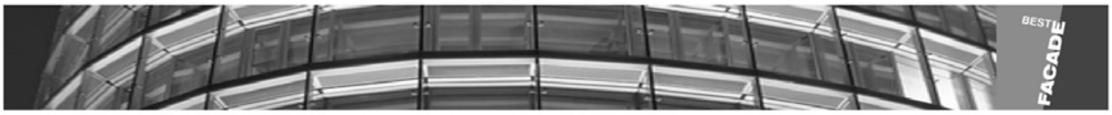
24 hour average temperature: 0,0 °C

16 typical cold and cloudy winter day [hourly values in °C] — graph

1	2	3	4	5	6	7	8	9	10	11	12

13	14	15	16	17	18	19	20	21	22	23	24

24 hour average temperature: 0,0 °C



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

solar radiation file or comment

17 sum of total radiation on the horizontal in an average year 983 kWh/m²a

18 monthly total solar radiation [kWh/m²-mo]

1	2	3	4	5	6	7	8	9	10	11	12
11	22	55	103	171	176	170	133	75	42	18	8

19 total radiation on the horizontal on a typical hot and bright summer day related to climate of question number 12 [hourly values in W/m²]

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24

graph

20 total radiation on the horizontal on a typical cold and cloudy winter day related to climate of question number 13 [hourly values in W/m²]

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24

graph

air moisture file or comment

21 yearly minimum %

22 annual average humidity %

23 relative humidity on a typical hot and bright summer day related to climate of question number 12 [hourly values in %]

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24

graph

24 relative humidity on a typical cold and cloudy winter day related to climate of question number 13 [hourly values in %]

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24

graph

wind file or comment

25 main wind direction west please choose direction from the list

26 design wind velocity / speed ND m/sec

27 monthly average wind velocity [m/sec]

1	2	3	4	5	6	7	8	9	10	11	12
4,1	4,3	3,7	3,6	3,8	3,3	3,4	3,4	3,1	4,1	4,9	4,1

28 maximum wind velocity in 10 meter height (v_{10}) ND m/sec **info**

29 average wind velocity in 10 meter height (v_{10}) ND m/sec **info**

30 maximum wind velocity on the top of the facade ND m/sec **info**

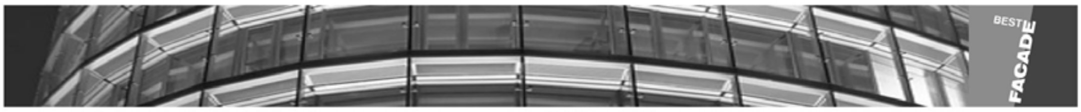
noise and air quality file or comment

31 ambient noise level L_{equ} (day / night) ND dB (A)

32 surroundings

- ☐ big city
- ☐ main street(s)
- ☐ industrial area
- ☑ small town / village
- ☐ open landscape
- ☐ seaside

All surrounding buildings are much lower.



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

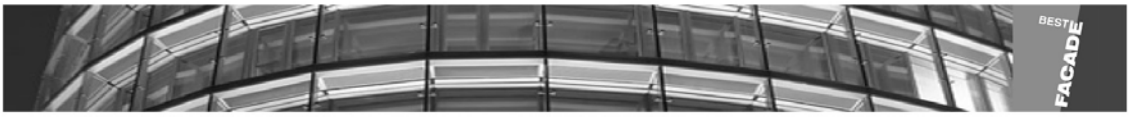
B information on the building

info to structure

	general			file or comment
33	identification of building	Kista Science Tower		
34	year the design process started	ND		
35	year of completion of building	2003		
36	height of the building above ground level	128,00	m	
37	width of the building (diameter)	26,00	m	
38	length of the building (diameter)	26,00	m	
39	total gross storey area	22000,00	m²	

	engaged institutions			info	file or comment
40	owner	Vasakronan	name		
		Stockholm/Sweden	city		
41	operating company / building promoter	Vasakronan	name		
		Stockholm/Sweden	city		
42	architect	Jan Larsson, White	name		
		Stockholm/Sweden	city		
43	contractor / building	NCC	name		
		Stockholm/Sweden	city		
44	contractor / facade	FFT - Feldhaus, Flexfasader, Trosa Glas	name		
		nsdetten Germany/Örebro Sweden/Trosa Swec	city		
45	energy conception	Theorells and NCC Teknik	name		
		Stockholm/Sweden	city		
46	HVAC	Theorells	name		
		Stockholm/Sweden	city		
47	static's	NCC Teknik and WSP	name		
		Stockholm/Sweden	city		
48	building physics		name		
			city		
49	acoustics		name		
			city		
50	fire protection	Brandskyddslaget	name		
		Stockholm/Sweden	city		
51	aerodynamics		name		
			city		
52	facility manager	Vasakronan	name		
		Stockholm/Sweden	city		
53	other engaged institutions	ACC Glasrådgivare	name		
		Nacka (suburb of Stockholm)	city		

	utilisation				file or comment
54	utilisation of the considered rooms behind the facade (please check only one item)	☐ residential	☐ office public	☑ office non public	
		☐ selling	☐ services	☐ production	Mainly IT firms e.g. Symantec, Unisys, Symsoft
		☐ industry	☐ hotel	☐ school	
		☐ other ...			
55	number of occupants per m² (gross storey area)	0,08		**info**	12 m²/person
56	weekly operating hours	65			



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

room heating system

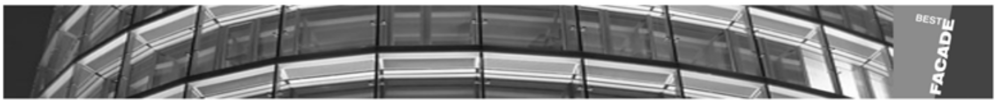
57	percentage of heated area (of gross storey area)	**100** %					**info**	
58	heat supply components	☐ under floor convector	☐ floor heating	☐ overhead radiation heating			**info**	Convector
		☑ radiator	☐ hot air heating	☐ activated concrete core				
59	type of used energy	☐ gas/oil %	☐ electricity %	☐ biomass %				
		☑ district heating 100 %	☐ solar %	☐ other %				
60	set point temperature heating		22	°C				
61	are the users able to influence the temperature		yes	please select				room thermostat
62	space heating demand		111	kWh/m²a				includes other bldgs

room cooling system

63	percentage of cooled area (of gross storey area)	**100** %				
64	cooling supply components	☐ under floor convector	☐ floor cooling	☑ overhead radiation cooling	**info**	Cooling beams
		☑ no cooling system	☐ cold air cooling	☐ activated concrete core		
65	type of used energy	☐ gas/oil %	☐ electricity %	☐ biomass %		
		☐ district heating %	☐ solar %	☐ other %		
66	set point temperature cooling		24	°C		
67	are the users able to influence the temperature		yes	please select		Room thermostat
68	cooling demand		42	kWh/m²a		includes other bldgs

electricity

69	total electricity consumption / m² gross storey area	93	kWh/m²a	**Info**	includes other bldgs
70	space lighting demand		kWh/m²a		
71	independent devices for energy production	ND		**Info**	



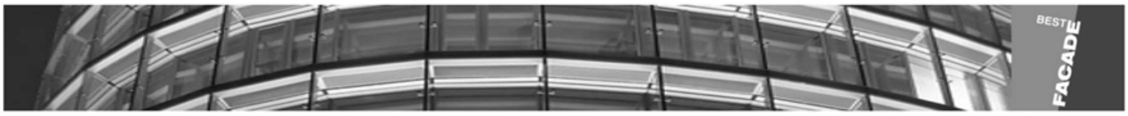
attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

room ventilation system

72	ventilation is operated by ... (multiple answers possible)	☐ opening windows into the gap ☐ opening windows to the outside by-passing the gap ☑ mechanical ventilation system	Balanced ventilation with heat recovery
73	air change rate of mechanical ventilation	during normal office hours 1,8 h^{-1} off time normal office hours 0,6 h^{-1} in summer nights 0,6 h^{-1}	
74	the mechanical ventilation system is able to ...	☐ humidify ☐ dehumidify ☑ preheat ☐ precool	
75	are the users able to influence the air change	no	please select
76	space ventilation demand	kWh/m²a	**Info**

by inhabitants reported comfort items - which disturbance appears ?

77	uncomfortable air temperature inside the rooms	☐ no ☐ yes .. in ☐ winter ☐ spring ☐ summer ☐ autumn further description:	☑ no data
78	uncomfortable airflow inside the rooms	☐ no ☐ yes .. in ☐ winter ☐ spring ☐ summer ☐ autumn further description:	☑ no data
79	radiative asymmetry the rooms	☐ no ☐ yeinside ☐ winter ☐ spring ☐ summer ☐ autumn further description:	☑ no data
80	glare problems inside the rooms	☐ no ☐ yes .. in ☐ winter ☐ spring ☐ summer ☐ autumn further description:	☑ no data
81	acoustic disturbance from outside	☐ no ☐ yes .. in ☐ winter ☐ spring ☐ summer ☐ autumn further description:	☑ no data
82	acoustic disturbance from inside (telephony effect)	☐ no ☐ yes .. in ☐ winter ☐ spring ☐ summer ☐ autumn further description:	☑ no data
83	too much transparency to outside	☐ no ☐ yes .. in ☐ winter ☐ spring ☐ summer ☐ autumn further description:	☑ no data
	too less transparency to outside	☐ no ☐ yes .. in ☐ winter ☐ spring ☐ summer ☐ autumn further description:	☑ no data
84	condensate	☐ no ☐ yes .. in ☐ winter ☐ spring ☐ summer ☐ autumn please note where condensation occurs according to the picture below :	☑ no data



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

measurement data

85 year of the measurement data: 2003-2005

86 time period

	summer	winter	
	☐ one day	☐ one day	The building automation system logs everything
	☐ one week	☐ one week	
	☐ from / to:	☐ from / to:	

	position of the measured data	outside	outer shell	facade gap	inner shell	inside
87	position of the measured data	outside	outer shell	facade gap	inner shell	inside
88	temperature [hourly values °C]	☑ yes ☐ no		☐ yes ☑ no		☑ yes ☐ no
89	relative humidity [hourly values %]	☐ yes ☑ no		☐ yes ☑ no		☐ yes ☑ no
90	sound level [hourly values dB]	☐ yes ☑ no		☐ yes ☑ no		☐ yes ☑ no

91 name of the file including the measured data

C general information on the facade

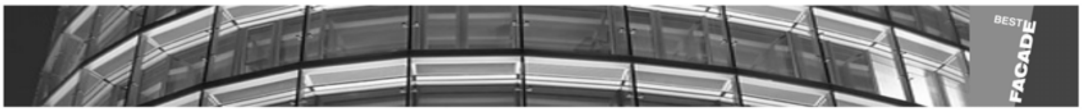
info to structure

general

				file or comment
92	erected in accordance with the building or for means of renovation ?	in accordance	choose item	
93	orientation of the facade	south	choose direction	
94	immediate vicinity	neighbours on two sides	choose item	tallest building
95	U-value (mean of facade)	ND	W/m²K	
96	sound absorption rate (mean of facade)	ND	dB(A)	

shading

97	the facade is shaded by	☐ buildings	☐ topography	☐ plants	tallest building
98	period of the day with direct solar radiation on the facade on a typical bright summer day	direct radiation from	7:00 am	to	6:00 pm
99	period of the day with direct solar radiation on the facade on a typical sunny winter day	direct radiation from	9:00 am	to	3:00 pm



	attributes of the double skin facade:			KistaST/south/office	2005/11/04
	basic geometry of the whole facade				file or comment
100	width of facade (wf)	26,00	m		
101	height of facade up to top edge (hf)	128,00	m	Area **3328,0** m²	
102	height of bottom building (hb)	0,00	m		
103	height of bottom line of facade (hg)	4,00	m	**info**	
104	height between floors (hbf)	4,00	m		
105	number of stories behind the facade	31	-		
106	width of gap (wg)	0,70	m		

	ventilation type of façade *(following BBRI, 2005)*				file or comment
107	type of ventilation of the gap (only 1 per facade)	natural	choose item	**info**	

Partitioning of the gap of the façade *(following BBRI, 2005)*

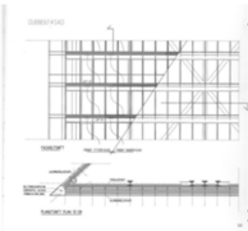
Choose only one of the following possibilities per facade! **info**

file or comment

108	☐ 1) Ventilated double window	height of the window [ ] m	width of the window [ ] m	**info**	
109	☐ 2) Facade partitioned per storey with juxtaposed modules	height of the module [ ] m	width of the module [ ] m	**info**	
110	☑ 3) Facade partitioned per storey - corridor type	height of the corridor 4,00 m	width of the corridor 0,70 m	**info**	
111	☐ 4) 'Shaft-box' facade	height of the box [ ] m	width of the box [ ] m	**info**	
112	☐ 5) 'Multi-storey' facade	height of the gap [ ] m	width of the gap [ ] m	**info**	see "add. pics" 112
113	☐ 6) 'Multi-storey louver' facade	height of the gap [ ] m	width of the gap [ ] m	**info**	

☐ 7) Other

114 please ir



solar shading

115 design

- ☐ no shading system
- ☐ canvas screens
- ☑ Venetian blind
- ☐ wings
- ☐ other ...

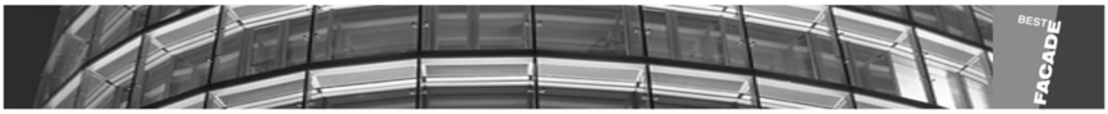
Perforated

116 please mark the position of the device

outside	outer shell	facade gap	inner shell	inside

☐1 ☐2 ☑3 ☐4 ☐5 ☐6 ☐7

117	percentage of heat transmission when activated (g value)	ND	%
118	reflectance when activated	ND	%



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

daylight control systems

design

120 ☑ no daylight control system ☐ prism ☐ segments ☐ light swords ☐ other

121 please mark the position of the shield

outside	outer shell	facade gap			inner shell	inside
☐1	☐2	☐3	☐4	☐5	☐6	☐7

122 daylight quotient when activated ND Tq

123 reflectance when activated ND %

control system

124
☑ no control system
☐ manual driven operated by occupants
☐ driven by engine and operated by occupants
☐ mechanical controlled with possibility to overrule by occupants
☐ mechanical controlled without possibility to overrule by occupants

artificial light

125 system HF fluorescent lighting

126 installed capacity (per m² gross storey area) 12,00 W/m²

control system

127
☑ operated by occupants
☐ centrally controlled with possibility to overrule by occupants
☐ centrally controlled without possibility to overrule by occupants

If the occupants forget to turn off the lights, they are automatically turned off at 21:00

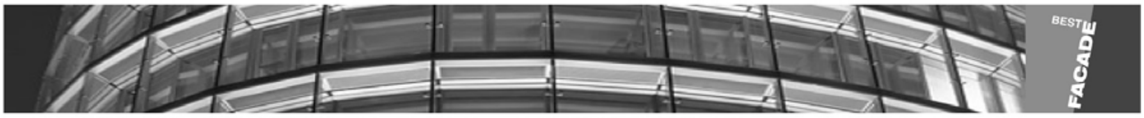
sound absorbers inside the gap

128
☑ no sound absorbers installed
☐ sound absorbers installed

location

129 please insert a drawing (sketch) of sound absorber here

130 please describe the material



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

further systems of building automation or fixtures in the facade

131	fire protection system	☑ no fire protection	☐ fire- / smoke detector	☐ sprinkler
		☐ other ... description		
132	active solar systems	☐ no		
		☑ yes ... description	heat pipes in the concrete close to the outer surfa	
133	photovoltaic	☑ no		
		☐ yes ... description		
134	pluvial protection devices	☑ no		
		☐ yes ... description		
135	radar damping system	☑ no	☐ interference	☐ absorption
		☐ yes ... description		
136	other	☑ no		
		☐ yes ... description		

D construction of the facade

info to structure

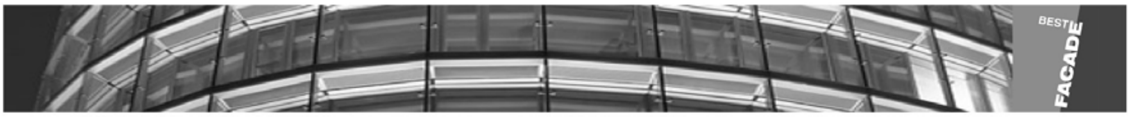
Please describe the most important sections (do not forget the shading system)

section 1

137

inside	width		material	file or comment
layer 01	0,4	cm	Clear glass	Fully glazed facade
layer 02	1,2	cm	Air	
layer 03	0,4	cm	Low emissivity glass	
layer 04	70,0	cm	Air cavity	
layer 05	1,0	cm	Clear glass	
layer 06		cm		
layer 07		cm		
layer 08		cm		
layer 09		cm		
layer 10		cm		
layer 11		cm		
layer 12		cm		
layer 13		cm		
layer 14		cm		
layer 15		cm		
outside				

138	U-value of section 1	ND	W/m²K
139	sound absorption rate	ND	db
140	g-value without activated shading system	ND	%
141	light transmittance Tau L without activated shading system	ND	%
142	g-value with activated shading system	ND	%
143	light transmittance Tau L with activated shading system	ND	%
144	fraction of section 1 on the outside surface area	ND	%



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

section 2

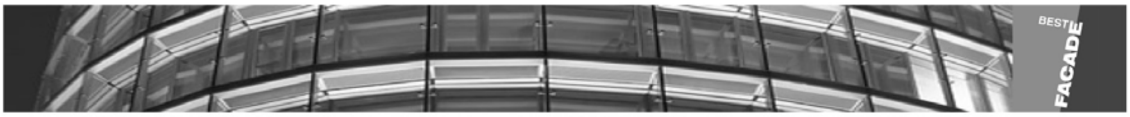
		inside	width	material	file or comment
		layer 01	cm		
		layer 02	cm		
		layer 03	cm		
		layer 04	cm		
		layer 05	cm		
		layer 06	cm		
		layer 07	cm		
145	please insert a drawing (sketch) of section 2 here	layer 08	cm		
		layer 09	cm		
		layer 10	cm		
		layer 11	cm		
		layer 12	cm		
		layer 13	cm		
		layer 14	cm		
		layer 15	cm		
		outside			

146	U-value of section 2	ND	W/m²K	
147	sound absorption rate	ND	db	
148	g-value without activated shading system	ND	%	
149	light transmittance Tau L without activated shading system	ND	%	
150	g-value with activated shading system	ND	%	
151	light transmittance Tau L with activated shading system	ND	%	
152	fraction of section 2 on the outside surface area	ND	%	

section 3

		inside	width	material	file or comment
		layer 01	cm		
		layer 02	cm		
		layer 03	cm		
		layer 04	cm		
		layer 05	cm		
		layer 06	cm		
		layer 07	cm		
153	please insert a drawing (sketch) of section 3 here	layer 08	cm		
		layer 09	cm		
		layer 10	cm		
		layer 11	cm		
		layer 12	cm		
		layer 13	cm		
		layer 14	cm		
		layer 15	cm		
		outside			

154	U-value of section 3		W/m²K	
155	sound absorption rate		db	
156	g-value without activated shading system		%	
157	light transmittance Tau L without activated shading system		%	
158	g-value with activated shading system		%	
159	light transmittance Tau L with activated shading system		%	
160	fraction of section 3 on the outside surface area		%	



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

E routing of air flow in the facade

info to structure

	projected main flow direction in the gap	**summer**	**winter**
161	vertical	☐	☐
162	diagonal	☑	☐
163	horizontal	☐	☐
164	none	☐	☑

summer activity

165	rate of air change in the gap	day	ND	h^{-1}	night	ND	h^{-1}
166	wind energy inside the gap		ND	% of outside wind energy			

winter activity

167	rate of air change in the gap	day	ND	h^{-1}	night	ND	h^{-1}
168	wind energy inside the gap		ND	% of outside wind energy			

ventilation openings in outer shell

169 for supply air ☑ yes ☐ no net area 75 cm²/m Facade

170 for exhaust air ☑ yes ☐ no net area 75 cm²/m Facade Net area per floor

171 net area different depending on location within height of facade ☐ yes ☑ no

172 type ☐ windows ☐ shutters ☐ segments ☐ grids ☐ other... slits

173 closable ☐ yes ☑ no

174 type of control

175 setting points "summer" / "winter"

176 ventilator ☑ no ☐ for supply air ☐ for exhaust air

177 rate of air flow m³/h

178 type of control

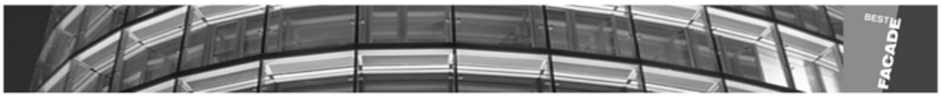
179 setting points

180 air filter ☐ yes ☑ no

181 smoke ventilation system ☐ yes ☑ no rate of air flow m³/h

182 air tightness of facade / ventilation openings measurement data available ☐ yes ☑ no

please specify /estimate openings per m²



attributes of the double skin facade: KistaST/south/office 2005/11/04

inner shell opens into the gap

183	for supply air	☐ yes ☑ no	net area	cm²/m Facade
184	for exhaust air	☐ yes ☑ no	net area	cm²/m Facade
185	net area different depending on location within height of facade	☐ yes ☑ no		
186	type	☐ windows ☐ lamellae ☐ other...		
187	closable	☐ yes ☐ no		
188	type of control			
189	setting points			
190	ventilator	☐ no ☐ for supply air ☐ for exhaust air		
191	rate of air flow	m³/h		
192	type of control			
193	setting points			
194	air filter	☐ yes ☐ no		
195	smoke ventilation system	☐ yes ☐ no	rate of air flow	m³/h
196	leak tightness of ventilation openings		data available	☐ yes ☑ no
197	please specify			

F maintenance

info to structure

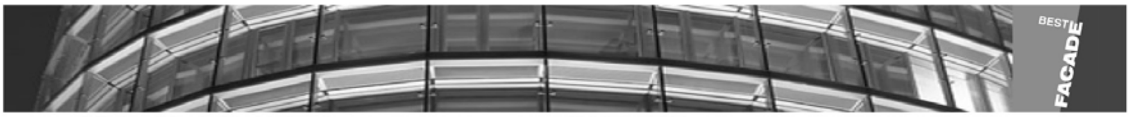
shells

outside	outer shell	facade gap	inner shell	inside
1		2 3		4

198	cleaning of surface 1	☑ by building cradle ☐ by lifting platform ☐ by cleaning robot ☐ from the gap ☐ other.... ☐ no cleansing	interval 2 a^{-1} (times per year)	
199	cleaning of surface 2	☑ from maintenance corridor ☐ from the interior ☐ no cleansing	interval 2 a^{-1} (times per year)	
200	cleaning of surface 3	☑ from maintenance corridor ☐ from the interior ☐ no cleansing	interval 2 a^{-1} (times per year)	only glas panels
201	cleansing of surface 4		interval 2 a^{-1} (times per year)	
201	service-intervals of surface 1	ND a^{-1} (times per year)		
203	service-intervals of surface 2	ND a^{-1} (times per year)		
204	service-intervals of surface 3	ND a^{-1} (times per year)		
205	service-intervals of surface 4	ND a^{-1} (times per year)		

facade fixtures

	type	cleaning-interval	service-interval
206		ND a^{-1} (times per year)	ND a^{-1} (times per year)
207		a^{-1} (times per year)	a^{-1} (times per year)
208		a^{-1} (times per year)	a^{-1} (times per year)
209		a^{-1} (times per year)	a^{-1} (times per year)
210		a^{-1} (times per year)	a^{-1} (times per year)
211		a^{-1} (times per year)	a^{-1} (times per year)



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

G costs

info to structure

erection costs facade

section 1

212

inside	width		material	costs €/m²
layer 01	0,4	cm	Clear glass	
layer 02	1,2	cm	Air	
layer 03	0,4	cm	Low emissivity glass	
layer 04	70,0	cm	Air cavity	
layer 05	1,0	cm	Clear glass	
layer 06		cm		
layer 07		cm		
layer 08		cm		
layer 09		cm		
layer 10		cm		
layer 11		cm		
layer 12		cm		
layer 13		cm		
layer 14		cm		
layer 15		cm		
outside				- €/m²

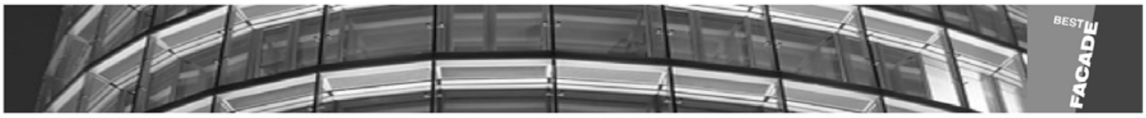
213 Summary costs of section 1 — 700-1000 €/m² — Single skin facade 400

section 2

214 please insert a drawing (sketch) of section 2 here

inside	width		material	costs €/m²
layer 01		cm		
layer 02		cm		
layer 03		cm		
layer 04		cm		
layer 05		cm		
layer 06		cm		
layer 07		cm		
layer 08		cm		
layer 09		cm		
layer 10		cm		
layer 11		cm		
layer 12		cm		
layer 13		cm		
layer 14		cm		
layer 15		cm		
outside				- €/m²

215 Summary costs of section 1 — ND €/m²



attributes of the double skin facade: **KistaST/south/office** **2005/11/04**

section 3

	inside	width	material	costs €/m²
	layer 01	cm		
	layer 02	cm		
	layer 03	cm		
	layer 04	cm		
	layer 05	cm		
	layer 06	cm		
	layer 07	cm		
216 please insert a drawing (sketch) of section 3 here	layer 08	cm		
	layer 09	cm		
	layer 10	cm		
	layer 11	cm		
	layer 12	cm		
	layer 13	cm		
	layer 14	cm		
	layer 15	cm		
	outside			- €/m²

217 Summary costs of section 1 ND €/m²

maintenance costs

	local energy tariff (if possible year 2004)			
218	natural gas/oil			€ / m³
219	electricity at peak time		0,08	€ / kWh
220	electricity outside peak time		0,08	€ / kWh
221	biomass			€ / kWh
222	district heating network		0,045	€ / kWh
223	other ...	district cooling	0,045	

	specific costs (if possible year 2004)			
224	heating for the rooms behind the facade	5	€ /m²a	
225	cooling for the rooms behind the facade	1,9	€ /m²a	
226	ventilation for the rooms behind the facade		€ /m²a	
227	lightning for the rooms behind the facade		€ /m²a	
228	total electricity cost	7,5	€ /m²a	
229	other ...		€ /m²a	
230	cleaning costs	1,9	€ /m²a	excl. inside the bldg
231	attendance costs		€ /m²a	

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