EIE/04/179/SO7.39459 KeepCool

Service Buildings Keep Cool: Promotion of sustainable cooling in the service building sector

Final Report

Imprint

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Content

1 Executive Summary

One of the fastest growing sources of new energy demand is space cooling. According to EU-studies a four-fold growth in air-conditioned space is likely to take place between 1990 and 2020. Space cooling places considerable strain on electricity systems in many European countries and is progressively affecting every EU country. In its preamble, the European Energy Performance of Buildings Directive (EPBD) explicitly calls for a *"passive cooling techniques, primarily those that improve indoor climatic conditions and the microclimate around buildings"* (European Communities, 2003, p. L1/66).

But such passive cooling technologies, which are already available and cost effective (such as use of well designed sun shades, efficient lighting and office equipment, passive cooling via thermal exchange with the ground, night ventilation etc.) are not widely used on the market today: the most common choice for a building owner when addressing summer comfort issues is still mechanical cooling, often without investigating other available measures.

In order to address this gap, the international project KeepCool was initiated in early 2005. The overall goal of the project was to facilitate market penetration of sustainable space cooling approaches and technologies in the participating countries, and implement activities that prevent a further increase of cooling demand in Europe. KeepCool addressed both newly constructed and existing service buildings in the public and private sector. Since the building owners are the driving force in the investment process, the project focused on convincing building owners on the benefits of sustainable cooling solutions through marketing and dissemination of already existing technologies, knowledge and tools. In addition, the project aimed at supporting the cooperation between suppliers and ensuring the link to norms and policy instruments that might support sustainable summer comfort.

The project had the following objectives:

- Increase awareness of existing sustainable cooling solutions that secure summer comfort in the participating countries;
- Enhance know-how-transfer between northern, southern, western and eastern Europe on the benefits, costs, chances, risks of sustainable cooling in building practice;
- Increase cooperation among companies supplying elements of sustainable cooling;
- Increase the number of implemented sustainable cooling solutions and make sustainable solutions an obvious discussion point both in new buildings and refurbishment projects;
- Influence the development of policy instruments which increasingly address the energy consumption for space cooling.

In order to make the information on the state of the art in passive cooling technologies usable for building owners and planners, we developed a logical pathway to reduce cooling energy demand in buildings, towards a target that we call "sustainable summer comfort". This approach provided the structure for a web-based toolkit for building owners, planners, building users and facility management professionals. The toolkit includes technology profiles to almost all steps, 14 Best Practice Projects in English and 41 in national languages (German, Lithuanian, Spanish), an analysis of the national comfort legislation and lists of experts and suppliers of passive cooling technologies in the participating countries. The toolkit is available at the project's Website www.keepcool.info.

Marketing and dissemination towards building owners and other target groups was the heart of the project. We applied a variety of direct and indirect marketing methods, from concrete advice in existing projects, over organising or presenting at events of the target groups, media articles and websites, university education to presentations and discussion at international conferences.

In addition to the direct impact on the market, the project succeeded to influence standards and national energy policies so that these support sustainable summer comfort. We brought in important changes into the European standard prEN 15251 "Indoor environmental input parameters for design and assessment of energy performance of buildings - addressing indoor air quality, thermal environment, lighting and acoustics", succeeded to introduce limits of cooling demand in the harmonised Austrian Building code, and had influence on environmental subsidy programs in Austria, Italy and Spain.

In conclusion, KeepCool provided a good base for the market transformation from "cooling" to "summer comfort". It brought together the results of many research projects into one consistent approach for sustainable summer comfort, and developed understandable information material for the most important target groups. In addition, it contributed to European and national regulations that promote summer comfort with the help of passive cooling and low energy strategies, and started with market implementation in eight European countries, delivering important experience on the success factors and barriers on the market.

Future actions in the field can use the results of our project for further market transformation activities: they can continue to tackle the identified market barriers, and by doing this, they can employ the dissemination principles that proved to be most successful during the course of KeepCool. A great opportunity to overcome the four identified barriers is given in the relevant EU Directives: in its introduction, the EPBD is explicitly calling for "strategies which enhance the thermal performance of buildings in the summer period" (European Communities, 2003, p. L1/66). In addition, the new Directive on Energy End-Use Efficiency and Energy Services (EEE-ESD) is setting energy saving targets for the European Union and the Member States, and requires an Energy Efficiency Action Plan (EEAP) as well as energy efficiency criteria in public procurement schemes from each Member State (European Communities, 2006). Both instruments allow for the broad implementation of measures that help to consolidate the market for Sustainable Summer Comfort technologies, to support integrated planning and to make use of the newest standards in the design of cooling equipment. In turn, Sustainable Summer Comfort seems to be a very effective means to fulfil the requirements of the EEE-ESD, as it leads to a considerable and long lasting reduction of the energy (and especially the peak energy) consumption of buildings.

2 Introduction

2.1 Background

Despite the available knowledge and technologies of passive cooling, cooling energy consumption is dramatically increasing in Europe. The studies EECCAC and EERAC predict a four-fold growth in air-conditioned space between 1990 and 2020 (Adnot et al, 1999; 2003, see also Figure 1). The IEA Future Building Forum even named cooling as one of the fastest growing sources of new energy demand (International Energy Agency, 2004).

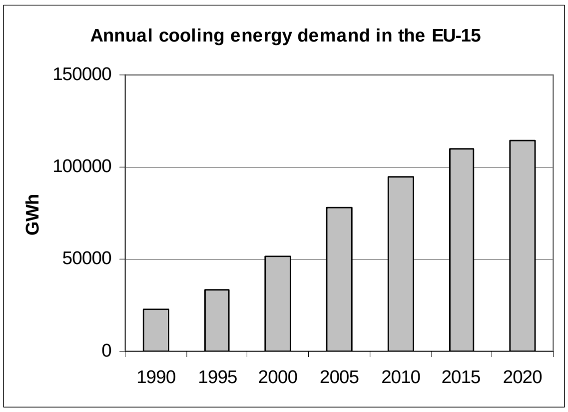

Figure 1: Annual cooling energy demand in the European Union, forecast by the project EECCAC (Adnot et al, 2003, p. 21).

Space cooling also places considerable strain on electricity systems in many European countries and is progressively affecting every EU country. The preamble of the European Energy Performance of Buildings Directive (EPBD) takes up this issue, stating:

> *“Recent years have seen a rise in the number of air-conditioning systems in southern European countries. This creates considerable problems at peak load times, increasing the cost of electricity and disrupting the energy balance in those countries. Priority should be given to strategies which enhance the thermal performance of buildings during the summer period. To this end there should be further development of passive cooling techniques, primarily those that improve indoor climatic conditions and the microclimate around buildings”* (European Communities, 2003, p. L1/66).

Such passive cooling techniques are already available and cost effective (such as use of well designed sun shades, efficient lighting and office equipment, passive cooling via thermal exchange with the ground, night ventilation etc.). However, they are not widely used on the market today: the most common choice for a building owner when addressing summer comfort issues is still mechanical cooling, often without investigating other available measures.

2.2 The KeepCool project

In order to address this gap, the international project KeepCool was initiated in early 2005. The overall goal of the project was to facilitate market penetration of sustainable cooling approaches and technologies in the participating countries, and implement activities that prevent a further increase of cooling energy demand in Europe. KeepCool addressed both newly constructed and existing service buildings in the public and private sector. Since the building owners are the driving force in the investment process, the project focused on convincing building owners on the benefits of sustainable cooling solutions through marketing and dissemination of already existing technologies, knowledge and tools. In addition, the project aimed at supporting the cooperation between suppliers and ensuring the link to norms and policy instruments that might support sustainable summer comfort.

In particular, KeepCool had the following objectives:

- Increase awareness of existing sustainable space cooling solutions that secure summer comfort in the participating countries;
- Enhance know-how-transfer between northern, southern, western and eastern Europe on the benefits, costs, chances, risks of sustainable cooling in building practice;
- Increase cooperation among companies supplying elements of sustainable cooling;
- Increase the number of implemented sustainable cooling solutions and make sustainable solutions an obvious discussion point both in new buildings and refurbishment projects;
- Influence the development of policy instruments which increasingly address the energy consumption for space cooling.

2.3 Target groups

The KeepCool project had four main target groups:

- Building owners (core target group),
- Building users,
- Operation and maintenance staff,
- Technical consultants.

The interaction of all these target groups determines design and use of summer comfort technologies. This interaction is a complex process that varies from object to object. As investors and decision-makers, **building owners** can set up requirements for buildings in general and specific targets on summer comfort. Thus, they are able to set the framework for the planning process. Building owners are connected with the **building users** and with the **operation and maintenance (O&M) staff** via contractual agreements. These contracts might also contain comfort levels or operational prescriptions. **Building users** influence both the performance of the building (choice of room temperatures, operation of windows, contribution to internal heat loads) and the energy performance through rental agreements. **O&M staff** need information on how sustainable summer comfort technologies are operated, and are also important as a link to the building users. For complex projects, building owners are increasingly accompanied by **technical consultants** of different fields (see Figure 2).

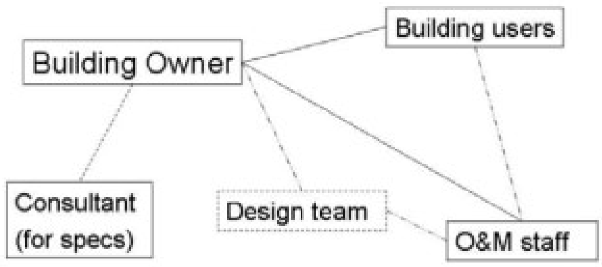

Figure 2: Relationships between actors in service buildings: Contractual agreements between building owners, building users and the O&M staff (full lines). Advice from consultants to the building owner (dashed lines). Informal communication between most target groups (semi-dashed lines).

2.4 The KeepCool consortium

The composition of the consortium allowed exchange of knowledge between the different climatic and cultural regions in Europe. Table 1 details the countries and organisations participated in the project and Figure 3 shows the project consortium at its third Interim Meeting:

Country	Participant in KeepCool	Short Name
Austria	Austrian Energy Agency, Coordinator	AEA
Austria	AEE INTEC	AEE INTEC
Germany	IZES gGmbH	IZES
Italy	End-use Efficiency Research Group, Dipartimento di Energetica, Politecnico di Milano	eERG
Lithuania	Lithuanian Energy Institute	LEI
Portugal	Centro de Estudos em Economia da Energia, dos Transportes e do Ambiente	CEEETA
Scotland	NIFES Consulting Group	NIFES
Spain	Andalusian Energy Agency	AAE
Sweden	Swedish Energy Agency	STEM

Table 1: Participants of the KeepCool project

Figure 3: The KeepCool Consortium at its Third Interim Meeting at the CEEETA office in Lisbon, Portugal. From left to right: Carlos Lopes, STEM; Lotta Bangens, ATON (subcontractor to STEM); Charlotta Isaksson, AEE INTEC; Jaime Martinez Davison, AAE; Klemens Leutgöb, AEA; Márton Varga, AEA; Lorenzo Pagliano, eERG; Eugenijus Perednis, LEI; Graham E. F. Read, NIFES; Ralf Cavelius, IZES; and Carlos Laia, CEEETA.

3 Sustainable summer comfort

3.1 Definition and approach

The average efficiency of electricity generation in Europe is about 36%[1], and other losses are present in the chain from electricity to the final useful service delivered. Hence energy saved at the end-user level has a larger effect on reducing demand of energy resources, investments in the energy chain and of impact on the environment than any other measure. Therefore our logical path to sustainable summer comfort will necessarily start from analysing the means to reduce energy demand at the user level.

Sustainable summer comfort can be defined as "achieving good summer comfort conditions with no or limited use of resource energy[2] and through the use of environmentally non-harmful materials".

Instead of setting maximum energy input or prescribing certain technologies to be used, we propose a logical sequence of steps that should be considered when designing, constructing and operating a building. This approach has the advantage of leaving ample freedom to designers while supporting them in adapting the building to the local situation (climate, culture, locally available materials). Not all steps and actions will be available in a specific situation to the owner/designer, but our suggestion is to follow this path and closely analyse the possibilities for action in a given situation for each step:

1. Define explicitly the thermal comfort objectives, using the Adaptive Comfort model where possible.
2. Intervene on the site layout and features which can affect summer comfort.
3. Control and reduce heat gains at the external surface of the envelope.
4. Control and modulate heat transfer through the building envelope.
5. Reduce internal gains.
6. Allow for local and individual adaptation.
7. Use passive means to remove energy from the building.
8. Use active solar assisted cooling plants.
9. Use high efficiency active conventional cooling plants.
10. Train building managers and occupants on how to use, monitor the performance of and adequately operate and maintain the building.

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[1] This is the ratio of electric energy generated to the energy content of the fuel input to the electric power plant. When considering the entire process of extracting the resource from the ground (e.g. crude oil, natural gas, coal), preparing, transporting, converting it in a power plant and finally distributing it the overall efficiency of this chain of processes is considerably lower. Other losses are then present in the chain from electricity to the final useful service delivered.

[2] Resource energy is defined as "energy taken from a source which is depleted by extraction (e.g., fossil fuels)" in the CEN norm on "Heating systems in buildings — Energy performance of buildings — Overall energy use, primary energy and CO_2 emissions".

Following these ten steps of our sustainable summer comfort process means to:

(i) consider the building as a whole and its multiple interactions with its environment and

(ii) exploit envelope/passive measures (e.g. building envelope design, climatic conditions and natural energy sources) to achieve the desired - and explicitly stated - comfort objectives.

This is the contrary of the design process that is often prevailing today. Here, design architects/engineers tend/are forced to delegate the achievement of comfort conditions to HVAC engineers, which in turn cannot intervene in decisions about building envelope, lighting systems, and not even the building layout which affects the placement of mechanical equipment and ducts. In this way, internal comfort is achieved primarily through active measures, i.e. cooling and ventilation based on importing fossil energy into the building. The result of this lack of integration is a large number of buildings which are less pleasant to inhabitate, more costly to build and several times more costly to keep comfortable in summer than they should be.

3.2 Ten steps to achieve sustainable summer comfort

3.2.1 Define the thermal comfort objectives explicitly, using the Adaptive Comfort model where possible

Mostly, regulations require keeping upright a constant indoor temperature, regardless of the outdoor conditions. These prescriptions come sometimes from a unduly rigid interpretation of the underlying comfort model of Fanger (1970), that proposes to predict the comfort vote of the occupants of a building as a function of the indoor air temperature, surface temperatures, humidity, air velocity, their assumed activities and clothing. The idea behind this comfort model is the assumption that people feel comfortable at a temperature level where there is no heat exchange between them and the environment (steady-state). The surveys for constructing a correlation between the above variables and the comfort vote were performed in climate chamber experiments.

At the same time, Nicol and Humphreys (1972) proposed the Adaptive Comfort model that states that people in real buildings, naturally ventilated, tend to adapt their comfort requirements to the prevailing outside temperatures. This model takes into account that people in real life situations are not functioning at constant conditions; instead, they vary their activities, metabolic rate and clothing according to the climate and its variations. Thus, the optimum indoor temperature (that is the one at which occupants will report comfort) varies with the outside temperature; in particular, it has a correlation with the average external temperature in the last few days. The correlation is derived from interviews to occupants of real, free running buildings (the results and analysis of these interviews are presented in the SCATs database and the ASHRAE RP 884 database).

The Adaptive model of comfort has wide implications on the application of passive cooling methods and energy use for achieving summer comfort. As the indoor comfort temperature varies in time in correlation with the average of the outside temperature, the difference between the two temperatures tend to be lower, and consequently cooling loads tend to be lower than in buildings with fixed temperature set points. Further, the slightly fluctuating indoor comfort temperature under the Adaptive Comfort Model is more likely to be achieved by passive cooling methods than the fixed temperature set point derived from a rigid interpretation of the Fanger model and hence does not put passive architecture at a disadvantage. The Adaptive Comfort Model and the way it has been included into the European standard EN 15251 is described in detail below in this report.

3.2.2 Intervene on the site layout and features which can affect summer comfort

A compact urban layout may be useful to reduce irradiation on external surfaces in hot dry climates, while an openly spaced layout might be required in humid areas to increase ventilation possibilities; the presence of vegetation and surface water, the choice of materials and finishing with low values of solar absorbance for urban surfaces (streets, parking spaces,…) can strongly influence surface and air temperatures in open spaces surrounding the buildings.

3.2.3 Control and reduce heat gains at the external surface of the envelope

Heat enters through the external surface or boundary of the building because of solar radiation and of the difference between outside air temperature and inside air temperature (see Figure 4). A high reduction of the amount of heat going through the external surface (or boundary) can be achieved by means of solar protections designed to shade windows when required (and possibly also walls and roofs), by surface finishings with adequate values of reflectivity and emissivity, and by means of limiting air exchanges when outside air is at higher temperature than inside air.

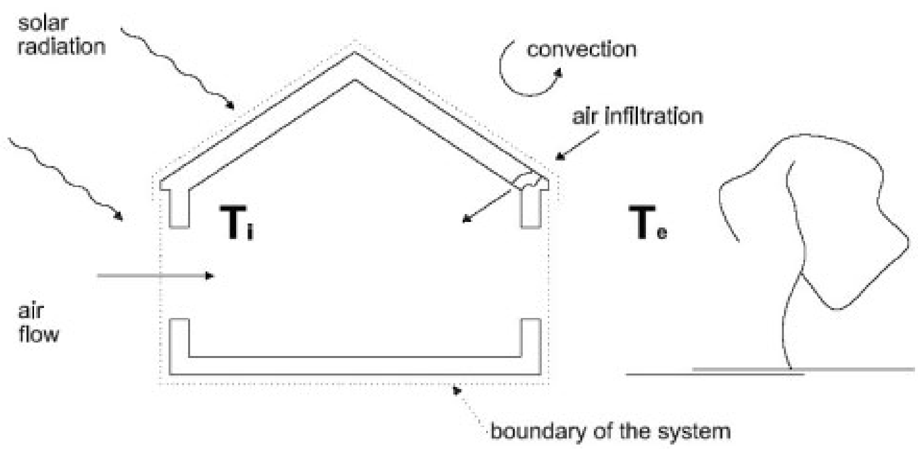

Figure 4: Thermal energy flows though the boundary separating the building and its environment because of absorption of solar radiation, convection exchanges with the atmosphere, air infiltration and air flows through cracks and openings.

3.2.4 Control and modulate heat transfer through the building envelope

Once heat has passed through the external surface or boundary, its movement to the interior (via heat conduction and convection) should be limited by appropriate use of insulating materials and the time lag by which it gets to the interior should be controlled by appropriate size and position of thermal mass.

3.2.5 Reduce internal gains

Internal gains should be reduced by using efficient lighting sources and systems (notably the most efficient one, daylight); by direct venting of spot heat sources; by using efficient appliances and office equipment and by ensuring that all systems are turned to stand-by or off when not in use. The internal gains due to a high density of occupants and/or of equipment in special locations (e.g. in conference rooms etc.) need to be duly taken into account as for the possible need of active cooling in this case.

3.2.6 Allow for local and individual adaptation

Allow for local and individual adaptation via a flexible dressing code, low thermal insulation furniture, use of ceiling fans, and flexible working hours during high temperature periods up to a few days of "heat wave holidays"[3].

3.2.7 Use passive means to remove energy from the building

Once having reduced external and internal gains and having allowed means to individually adapt, if the desired comfort objectives are still not met, use passive means to remove energy from the building and/or increase comfort (comfort daytime ventilation, night ventilation, use of the ground as a sink where to discharge heat removed from the building, open groundwater or surface water systems, radiation of energy to the night sky, direct or indirect evaporative cooling).

An important issue here is the definition of a passive measure. We adopt the definition given by Givoni (1991, p. 177):

> *"the term passive (…) does not exclude the use of a fan or a pump when their application might enhance the performance. This term emphasizes the utilization of natural cooling sources, or heat sinks, for the rejection of heat from the building and, if some power is needed to operate the system, that the heat transfer system is low cost and simple and that the ratio of power consumption to the resulting cooling energy is rather low (…)".*

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[3] In the same way as schools and offices may be closed in winter as a consequence of a snowfall

3.2.8 Use active solar assisted cooling plants

If passive means are not sufficient to achieve the thermal comfort conditions assumed as an objective at step number 1 for a sufficient fraction of time, then remove the excess thermal energy from the building via active solar assisted cooling (e.g. absorption and adsorption cycles driven by heat from solar collectors).

3.2.9 Use high efficiency active conventional cooling plants

If steps 1-8 are still not sufficient to achieve the desired thermal conditions, use conventional active cooling plants with high efficiency. Design this active system always in combination with steps 1-8 so that they are only responsible to remove peak loads in extreme hot times or in special parts of the building, and the major drive towards summer comfort is provided by the previous steps. In case of existing buildings with existing HVAC systems, try to use steps 1-8 to reduce cooling loads and improve the efficiency of the existing plant using the same approach, i.e. starting from as close as possible to demand. This means intervening first at the level of the diffusion of cold air to the internal environment, going then upward to the distribution system (air or water), reducing pressure drops in the ducts (straight ducts layout, choice of low friction elements) and leakages, increasing the efficiency of heat exchangers, shading the condensers from the sun, using efficient fans, pumps and motors with variable speed regulation. Intervening in these ways to reduce losses in the chain allows finally for the use of a smaller size vapour compression cycle.

3.2.10 Train building managers and occupants on how to use, monitor performances and adequately operate and maintain the building

Having followed the previous steps, the integrated system “building and plants” (rather than only the active plants) is the means for reaching comfort conditions. Clear and exhaustive manuals should be prepared, and an initial training provided, to allow the management staff and the occupants of the building to know how to rationally operate and control the building and its systems/plants when present. For new buildings, a monitoring plan should be prepared to assess whether the performance (comfort, consumption) of the building matches the design objectives and the persistence of good performance over time. A maintenance plan should be followed (ordinary planned maintenance and extraordinary maintenance when decay of performance is detected)[4].

[4] It should be noted that point 10 is not a burden which is connected to the choice of passive techniques. On the contrary in the case of the presence of an active cooling plant all the above actions are also necessary, and the technical complexity of the plant requires specific training.

3.3 Brief descriptions of selected technologies

3.3.1 Comfort models

Why are comfort models important to well being and energy saving? Because they describe quantitatively (based on large surveys of people interviewed on their subjective comfort sensation) in which range of conditions people will feel thermally comfortable in buildings, and because choosing a too narrow range of conditions might imply “unnecessary consumption of energy”, using the wording of the Building Performance Directive. There are two prevailing comfort models:

- the comfort model originally proposed by Fanger or Predicted Mean Vote (PMV) model,
- and the model which takes into account the adaptation to the prevailing climate of occupants of buildings (Adaptive comfort model).

In the Fanger model the optimum internal condition for a building (that is the one at which occupants will report comfort[5]) is correlated exclusively to parameters referring to conditions internal to the building (as air temperature and velocity, mean radiant temperature, air humidity) and to clothing level and metabolic rate of the occupants. Correlation between the subjective sensation of comfort and those parameters was obtained through tests with occupants of controlled closed rooms. Since the model is often used assuming ‘typical values’ of clothing and metabolic rate, fixed once for all for the entire summer season, it might lead to specify a static, narrow band of ‘comfortable’ room temperatures to be applied uniformly through space and time. In these cases it may unduly disfavour the use of passive technologies, whose aim is to moderate external temperature fluctuations without completely decoupling the indoor environment form the external one.

The Adaptive comfort model proposes a correlation between the temperature reported as comfortable by occupants of a building with the temperature of the external air. More precisely, the model relates the comfort temperature of occupants to a moving average of past external temperatures where more weight is attached to the temperatures of more recent days. The underlying concept is the documented process of adaptation of the body and the metabolic rate to the climate and its variations, and hence the fact that the temperature reported as comfortable by occupants of a building varies with season and location. The correlation is studied in the field, with occupants of real buildings and leads to the conclusion that a wider range of temperatures are considered comfortable than prescribed by the Fanger model. The Adaptive model allows for a easier integration of passive cooling technologies.

The two models are applicable in different conditions, roughly speaking the Fanger model in mechanically conditioned buildings (where temperatures, humidity, air velocities etc. must be kept within specified ranges), and the Adaptive model in non-mechanically conditioned or naturally ventilated buildings. The ASHRAE and the new EN 15251 standards propose the use of the Adaptive approach only for non-mechanically conditioned buildings. Further

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[5] Comfort means the subjects vote either “+1 slightly warm”, “0 neutral” or “-1 slightly cold” on the 7 point ASHRAE scale, ranging from “+3 hot” to “-3 cold”.

studies are underway to explore its applicability also in mechanically conditioned or mixed-mode buildings and preliminary studies (e.g. the ACA-SCATs study, McCartney and Nicol, 2002) show positive results both in terms of comfort and energy savings. Importantly when evaluating summer conditions, a correction should be used to take into account the increase of comfort produced by increasing air velocity by the use of natural ventilation or fans.

The implications of the use of the two models are described by de Dear and Brager (2002):

> "If a building's interior conditions were able to be maintained within the Adaptive Comfort limits entirely by natural means, then one could potentially save 100% of the cooling energy that would otherwise be used by an air-conditioner to maintain conditions within the more narrow ASHRAE Standard 55 (based on Fanger model) comfort zone. If one were to apply the Adaptive Comfort to a mixed-mode building, however, the air conditioner might be used in a limited way to keep the more extreme temperatures from rising past the acceptability limits of the Adaptive Comfort Standard. In this case, the energy savings would be proportional to the difference between set-points defined by the upper limit of the Adaptive Comfort Standard, compared to typical set-points used in an air-conditioned building. (…) Savings are likely to be much higher than indicated since it is more common to find buildings operating at the center of the ASRHAE Standard 55 comfort zone (approximately 23°C) than at the upper end of 26°C."

In order to move building design closer to real-life comfort requirements and at the same time to reduce cooling energy demand, we propose this model to be adopted in building regulations and construction norms wherever appropriate. Together with Prof. Fergus Nicol, one of the founders of the Adaptive Comfort model, the KeepCool team succeeded to introduce this model into the standard EN 15251 "Indoor environmental input parameters for design and assessment of energy performance of buildings - addressing indoor air quality, thermal environment, lighting and acoustics". The technical details how the Adaptive Comfort model was taken up in this regulatory framework are described in section 5.2 below in this report.

3.3.2 Solar shading

Solar shading devices play a decisive role in energy conservation and comfort performance in cooling dominated climates and summer seasons. In summer, solar radiation through transparent façade in fully glazed office buildings may be responsible for 70% of the peak cooling load. An external shading system with a shading coefficient of 10-15% may drastically reduce this load, while still allowing some daylight to get into the building from diffused and redirected radiation. Moreover, external shading devices reduce the temperature of the internal surface of the glazing when sun radiation hits the window and this also reduces local thermal discomfort close to the windows.

The adoption of internal or external sun shading devices are often the only way to prevent from glare effects on desks an monitors, that may cause strong restrictions in the use of the spaces which are very close to the windows. In winter, moveable devices permit visual control and better use of daylight and solar heat gains avoiding glare effects. Glare sometimes forces users to completely obscure the window and turn on electric lighting. In these cases, the adoption of indoor Venetian blinds or white diffusing tends may have energy and comfort benefits both on lighting and heating demands.

Various ways have been experienced to provide effective window protection. These can include proper orientation, sizing and location as well as wall protection, colonnades, balconies and roof overhangs. However, the most common and flexible form of protection is the use of shading devices.

Usually shading effectiveness strongly depends on:

- the positioning of the shading device with respect to glazing and window components
- the geometry of the device,
- the incident angle of the radiation,
- the optical properties of the surfaces (diffuse and specular reflectance),
- the control options (for moveable devices)

Physically, we can classify window shading device in order of their thermal interaction with glazing which depend on their positioning, external or internal, and in order of their capability to face and follow Sun direction, moveable or not.

Movable devices

All movable devices, as Venetian blinds, offer the advantage that can be controlled manually or through automation, adapting their function to time of day and season. So that, for instance, when Sun is high or does not impinge the window surface, slats are open and allow daylight and external view.

Internal blinds

Inside blinds are very common window protection schemes. They are very easy to apply but their main effect is (when well designed) to help control lighting levels and uniformity. In order to maintain visual contact with the outdoor environment, one my choose blinds which rise from bottom rather than descending from top of the window.

Inside blinds are generally ineffective in reducing the summer heating load because they block radiation when it is already in the room. Only if well designed (with high reflectance finishing) and combined with spectrally selective glazing, they can provide some advantage in solar control and daylight use strategies.

Some care has to be taken if the blind surfaces are light coloured since they might look very bright and cause glare discomfort.

External blinds

External blinds stop solar radiation before it enters the room (as all external shading devices do) and for this reason are the best effective in solar control strategies.

The blinds should be covered with reflective finishing, in order to reduce the amount of energy they absorb and radiate towards the building. It is also advisable to adopt solutions which allow air movement between the blinds and the window in order to remove the energy absorbed by the blinds.

However, one has to regard side effects that can be created by external blinds, as for example:

- block heat between blind and window. This can be avoided by separating the shading device form the building, and by using open, e.g. louvred shading devices
- interfere with air- flow for ventilation

Blinds between two layers of glass

These devices have the blinds between the 2 glass layers of a window. They are efficient in blocking both direct and diffuse radiation, as well as allow winter sun since their slats can be tilted.

But they also have some disadvantages:

- radiation enters in the area in between the two glasses, increasing the temperature and allowing, thus, some of the heat to reach the room.
- vapour condensation might occur between the two layers of glass in winter if there is air infiltration into the cavity.

Awnings or movable fins

In order to combine advantages of the fixed devices and the flexibility of the movable ones, awnings and movable fins have been created.

Permanent devices

Permanent devices are in general devices designed for a specific building, and are less flexible than movable ones.

Overhangs

They are relatively widespread in hot climates. Their major advantage is that if positioned correctly, they admit direct radiation when the sun is low in winter while blocking it in summer (they block also part of the diffuse radiation).

The main limit of their use is that they are appropriate only for south windows. East and west have low and variable sun angles, thus other (vertical) devices have to be applied.

Side effects: they may interfere in the air flows inside as well as outside the building.

Vertical protections - fins

Vertical protections have mainly been used to shade east and west windows. They can be designed alone or in combination with overhangs. They prove to be effective on diffuse radiation.

The disadvantages of such devices are:

- they strongly affect view.
- they may interfere in the air flows inside as well as outside the building.

Louvres

Although louvres are most commonly used as permanent devices, they can be used also as movable ones: they appear then as a 'giant' external Venetian blind. If they are movable, they can obviously block summer radiation (being partially effective also for the diffuse radiation) while allowing winter sun. If they are fixed they may also efficiently contribute to security.

On the other hand they may have the following disadvantages: affect view (especially if they are permanent) and stress the need of artificial lighting. Finally, louvres may modify air movements (either facilitate or hinder natural ventilation) depending of their geometry, their inclination and the environment of the building.

There are different types of louvres. Some types is formed of specially shaped reflective louvres that reject the high-angle direct sun but reflect lower-angle light up to the ceiling (increasing, thus, utilisable daylight and allowing energy savings and comfort).

Lightshelves

A very interesting device that can combine both daylight use and shading is the lightshelve device. The lightshelve is a horizontal reflective surface placed quite high next to the window or just outside it. By its appropriate position and by its interaction with overhangs, it shades the main part of the window but it allows light to reach the back of the room by reflection between the shelf and the ceiling.

Applicability of technology

Sun shading technologies may be applied in all new buildings and façade retrofits. The choice of the designers should take into consideration the local and specific conditions to deal with as well as the available technologies.

Overhangs and horizontal devices are suitable mainly for south facades, vertical mainly for east and west walls.

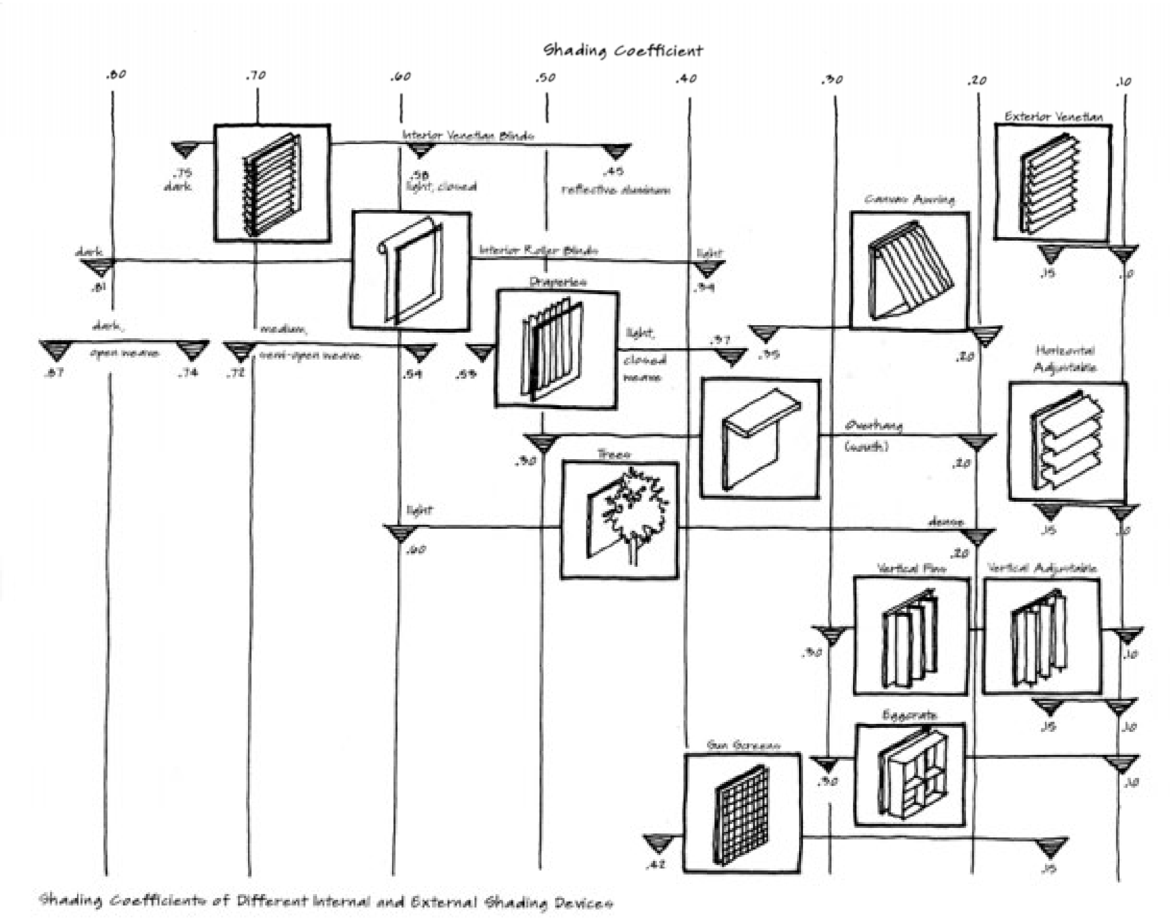

Figure 5: Shading Coefficient of Different internal and External Shading Devices.
(Source: Brown & DeKay, 2000)

It is worth saying that in the southern European climate, the direct solar radiation is very high in relation of the rest of Europe, the sky is more uniformly bright and there is significant illumination from ground reflectance. Overhangs are particularly favoured in these areas. This fact can be illustrated by many traditional solutions in the southern parts of Europe like the recessed windows in thick walls that are in effect provided with both overhangs and side-fins. However, they include also moveable louvred screens.

Care must be taken at the material selection of shading devices: Those made of heat absorbing and not reflective materials might create a heat bridge to the building.

Possible obstacles

Even if external shadings are always more effective in overheating prevention, they generally have great impact on the exterior appearance of the façade. In some cases, architectural conservation may restrict their application. In addition, high wind loads inhibit the application of external shading devices on high buildings. For both problems, a double-skin façade can be an appropriate solution.

3.3.3 Insulation

The building itself is a basic factor that influences the cooling requirements. Its envelope and construction greatly influence how much of the climate and internal loads are actually translated into the requirements. The design of refrigeration and air-conditioning equipment for buildings as well as components of the building thermal envelope depends on the principles of heat transfer theory. Heat transmission properties, such as thermal conductivity and diffusivity, for building materials and thermal insulation are important for the determination of heat transmission coefficients for these applications.

Insulation reduces the heat transfer through roofs, walls, the floor and windows. Depending on the temperature difference between inside and outside the heat flows through the building envelope from inside to outside or vice versa.

In cold regions insulation reduces the heating demand in winter, when the outside temperature is colder than inside. For all regions where the outside temperature is higher than the acceptable indoor temperature, insulation is recommended due to its reducing effect on the cooling demand.

In moderate and warm climate there is a significant potential for reductions of cooling energy demand if appropriate insulation is applied in combination with other measures.

Benefits

Lower (20-40%) cooling loads, which leads to lower energy costs and better thermal comfort. Insulation reduces the transmission of sound from other rooms or from the outside.

Typical cost indicators

- Operating costs: zero;
- Operating maintenance costs: zero;
- Investment costs: low-medium

Performance

Actual engineering knowledge about various materials to enable the calculation of an overall thermal character for most common building systems so that an overall thermal transmittance can be derived. Such values can be calculated for single glazed and double glazed windows, concrete slab floors, suspended wooden floors, walls and so on. These characteristics are usually written as a thermal transmittance (U-value) or a thermal resistance (R-value, used mainly outside of the Europe) for each of the various forms of construction and/or structural elements.

Favourable factors

- Building elements quite exposed to direct solar radiation;
- Building with active or passive ventilation strategy.

Unfavourable factors

- Building with external glazed walls.

Combination with other technologies

In order to improve the insulation effect it is necessary:

- minimise solar radiation;
- removal of heat (e.g. natural ventilation).

Barriers

In building retrofit, external insulation is not always possible (generally, in some conditions, the municipal building codes disallow it); internal insulation reduces habitable space and has limitations in taking care of thermal bridges.

3.3.4 Thermal Mass

The thermal capacity of a building, most of it due to thermally massive materials (so-called thermal mass) stores heat during the day and modulates indoor temperature swings. Each night the mass releases heat, making it ready to absorb heat again the next day. To be effective, thermal mass must be exposed to the living spaces. Buildings are considered to have average mass when the exposed mass area is equal to the floor area. Large masonry fireplaces and interior brick walls are two ways to incorporate high mass.

Passive cooling requires thermal mass: the source or sink not being available at the time that the cooling demand is maximum, makes necessary to store "coolness" during part of the day. Thermal mass in this case is internal mass. Its optimization depends on many parameters: climatic conditions, occupancy patterns, building orientation and use of auxiliary cooling. Thermal mass in its interaction with the other building elements is still not a closed subject in building research, and the effect of appropriate positioning of thermal mass might be very important. It is also important whether the surface of the mass is convectively or radiatively cooled.

Application

Thermal mass, coupled with convective cooling is more effective in the regions, which have a large diurnal temperature range (above about 15 K) and where the night minimum temperature in summer is below about 20°C. In such regions it's possible to store the coolness of the night air in the structural mass of the building.

Benefits

Lower (10-40%) cooling loads, which leads to lower energy costs and better thermal comfort.

Typical cost indicator

- Operating costs: zero;
- Operating maintenance costs: zero;
- Investment costs: low-medium.

Performance

Complex simulation techniques add a lag and decrement value or a set of response factors to describe the dynamic thermal behaviour of the element.

Favourable factors:

- Building with active or passive ventilation strategy.
- Building with discontinuous plant operation strategy (office).

Combination with other technologies

The ventilation strategy is highly relevant for the removal of heat during the day but also has to prevent infiltration when outside temperatures are higher than inside. Additional night ventilation might be useful to blow outside air at night into a building and cool its thermal mass allowing it then to absorb internal or external heat during the following day. Ambient air might be cooled in underground ducts e.g. in basements, underground car parks or gardens.

Barriers

If thermal mass is not sufficiently exposed to air flows, for example in office buildings with false ceilings and/or floors, it becomes ineffective in reducing air temperature fluctuations and storing “coolness” at night in a night ventilation strategy.

3.3.5 Reducing internal heat loads

What is internal heat load?

Knowing how and when a building is used is critical in determining the building’s heating and cooling requirements. Buildings that have high levels of use may generate so much internal heat that they need cooling in any season. The main internal heat sources are the people themselves, the electric lights they need and the electric equipment they use. People emit heat as a natural by-product of their living functions. Electric equipment and appliances contribute to the heat of a space as a by-product of their operation. Electric lighting turns electric energy into light and waste heat, whereby the light itself ends up as heat in the space.

Energy efficient office equipment and lighting reduce not only the energy costs due to their direct use, but also the energy costs for air-conditioning. In addition lower internal heat loads mean also that more buildings can remain with natural cooling, or air-conditioned buildings in intermediate climates can remain in a free-cooling state for a longer time.

Measures to lower internal heat load

Energy efficient office equipment

Energy savings about 40 up to 50% are economically feasible by:

(i) procuring energy efficient office equipment,

(ii) energy efficient use of existing equipment. These energy savings automatically lower the internal heat gains and help to reduce cooling demand to an extent that allows for passive cooling measures.

As an example, power requirement of different laser printer models can vary from 480 to 100 W while printing, and their stand-by consumption can vary from 90 to 20W. A ink-jet printer may consume 15 W while printing and 5 W in stand-by mode.

Energy efficient lighting

The energy efficiency of lighting systems can be improved with the combination of the following steps (the priority order must be determined from case to case):

1. Room Design: Light interior surfaces; daylight use
2. Selection of energy efficient luminaries
3. Selection of energy efficient lamps
4. Selection of energy efficient connecting devices (ballasts)
5. Energy saving lighting control systems
6. Maintenance: Regular cleaning and replacement

Heat from occupants cannot be influenced by technical measures

The heat emitted by the occupants cannot be influenced with a given use of a building. However, in office buildings, the heat emitted by the metabolic activity of people contribute marginally to the internal heat load, even though in other building types or special indoor spaces (e.g. conference rooms) heat form occupants can be a major contribution.

Energy saving potentials

The annual energy consumption of office equipment averages at 19 kWh/m^2a. Best practice values of around 7 kWh/m^2a can be reached with purchasing energy efficient office equipment, and using it in an efficient manner. Lighting consumes in average 45 kWh/m^2a in existing European office buildings, and up to 65 kWh/m²a in poor buildings. Large variations exist among the European countries: For example in Sweden the average lighting energy consumption in office buildings is 23 kWh/m²a, with maximum values at 53 kWh/m²a. These averages can be lowered to 12 kWh/m²a, along with constant or even increasing light comfort conditions. The lowest consumption detected was even lower: 6,6 kWh/m²a.

The above listed energy consumption results in average internal heat loads over the working day of around 30-40 W/m^2. In average, occupants contribute to that heat load with approximately 5 W/m^2, office equipment with 10 W/m^2, and lighting with additional 10-25 W/m^2. This additional heat requires additional cooling capacity. Given an average COP of the cooling system of 2,5, the corresponding additional energy demand for cooling is about 12-16 W/m^2.[6,7] If going for the best practice in both office equipment and lighting, a great part of this can be saved.

Measures to cope with a given (high) internal heat load

If production processes require constantly high internal heat loads, one can avoid discomfort or intense mechanical cooling with the following measures:

- Grouping heat sources in "hot spots";
- Appropriate room height: Gathering heat in places it does not cause discomfort;
- Displacement ventilation: Cooling where the cooling need is.

3.3.6 Individual adaptation

An adequate combination of local and individual adaptation factors with regards to local climate and buildings such as flexible clothing, furniture, air movement and activity would foster personal natural comfort (both psychological and physical) while reducing energy consumption within the context of sustainable cooling. These possibilities allow for the use of passive cooling in a greater variety of climates; on the other hand, they allow to set maximum temperatures higher in mechanically cooled buildings.

Clothing

Light summer clothing allows to feel comfortable at higher temperatures. Therefore, we recommend to relax dressing codes and adopt them to the prevailing outdoor climatic conditions. The following elements constitute light summer outfits:

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[6] Figures from the German guideline for electric energy in buildings, Leitfaden Elektrische Energie im Hochbau. Darmstadt: Institut Wohnen und Umwelt, July 2000. http://www.iwu.de/datei/lee-text.pdf

[7] These figures are calculated with average occupancy.

- No ties. Ties originate from the obligate scarf in the 19th century. They keep the collars of the shirts together, in order to keep the heat within the clothes in cold winters. Therefore, ties are not appropriate parts of summer outfits.
- No jackets in hot periods. There are possibilities to look formal without a jacket.
- Sandals. Closed shoes cause hot feet.
- Short-sleeved shirts. Allows better ventilation, therefore increases cooling effect of sweat evaporation.
- Short pants. Allows better ventilation, therefore increases cooling effect of sweat evaporation.
- Light materials: Linen, silk and cotton, or light synthetics (see ISO 7730/2005, Annex C for insulation values of clothing).
- Light colours: increases reflection of solar radiation, therefore reducing thermal gain from absorption of solar radiation.

Furniture

In sedentary work, not only clothing, but also the furniture influences thermal comfort. Normal chairs heat up, and work just like additional clothing. Both form and material influence the thermal characteristics of chairs. Specific “cool chairs” are available: These have a mesh structure on the back and/or seat, allowing the air to circulate around the body (here, again, insulation values are given in ISO 7730/2005, Annex C).

Air movement

Air movement increases the convective heat transfer coefficient and water evaporation velocity, and along with this the cooling capacity of the human body. This effect can be achieved and fostered by two main means: natural ventilation or forced air movement by portable or ceiling fans.

Natural ventilation through cross-ventilation is recommended when outdoor temperature is lower than indoor temperature. Hereby it is important not to open the windows at the façades that are actually exposed to the Sun: The air at these façades can be much hotter than the indoor air.

Air movement can be increased mechanically by portable fans and ceiling fans. There is an advantage with portable fans: users can better regulate personal efficiency of the fan, without interfering with other users. Fans may compensate a temperature increase of up to 2 to 3 °C (see ISO 7730/2005, Annex G).

Activity

Traditionally, working hours were directly linked to daylight hours. Besides daylight, temperature was another factor. Heavy duty work, and in general any outdoor labour (agriculture, building construction, etc.) could not take place at noon hours in hot climates.

Nowadays, working hours seem to be standardised throughout the Western world. However, this behaviour should be reconsidered: Just like the “summer time” is introduced throughout Europe, some countries and/or regions, depending on their local climates, should have a certain range of flexibility to adjust their standard working schedules to their specific climatic circumstances.

- Establish flexible entry and exit times to allow individual accommodation to high temperature periods.
- Change typical “9 to 5” office hours to a so called intensive or continuous shift or working day which goes from eight am to three pm with a short break (20-30 min.) for a breakfast.
- Consider “heat wave holidays” for people at risk in during high temperature periods.
- Allow for a “siesta” in hot regions or high temperature periods.

3.3.7 Passive cooling systems 1: Night ventilation (natural/mechanical)

Night ventilation makes use of the free cooling available from the ambient air at night by cooling the thermal mass. With natural ventilation heat gains accumulated during the day are removed and the building fabric cooled with ambient air from open windows and/or air vents.

Removal of the accumulated heat loads can be achieved with a variety of cross ventilation schemes that rely on wind induced flow or stack effect and /or mechanical ventilation. Natural ventilation is dependent on natural forces to move air through a building in most cases through the opening windows or the building facade. Mechanical ventilation systems have motorised fans and can maintain internal temperatures more accurately than natural ventilation systems.

Night ventilation may be applied to new or retrofit buildings without excessive internal gains.

Benefits

- Low cooling energy cost
- Low capital and maintenance costs

Typical cost indicators

- Capital – Low
- Energy – Low
- Maintenance – Low

Favourable factors

- Thermal mass
- Low internal gains

- Shallow plan (natural ventilation)

Spatial considerations

- space released for other use where cooling plant avoided

Combinations with other technologies

- evaporative cooling (with mechanical ventilation)

3.3.8 Passive cooling systems 2: Earth to air underground heat exchanger

The basic principle for the use of air circulated earth to air underground heat exchangers is the seasonal thermal storage ability of soil. This makes possible to use the soil for cooling in summertime and for heating in wintertime. The heat exchange should only be applied in climates with big temperature differences between summer and winter and between day and night. The heat exchange can be applied for heating of supply air, cooling of supply air and heating and cooling of the supply air.

Application

In cooling modus, the heat exchanger is suitable for independent cooling of indoor air as well as for the supply of another cooling system. Possibilities for cooling are natural night ventilation, mechanical night ventilation and building mass activation. Three applications of cooling with an underground heat exchanger are “comfort cooling”, “room cooling” and “supplement cooling”.

Benefits

Lower cooling energy costs, hygienically controlled air input if filters are installed and maintained (lower concentration of bacteria and fungi spores in the inlet air), possibility to reduce or avoid a conventional cooling system.

Typical cost indicators (relative to a conventional HVAC system)

- Operating costs – lower
- Operating maintenance costs – lower
- Investment costs - higher

Performance

Specific cooling energy yields of 300 Wh/m²d are possible. Further, peak loads of 30-40 W/m² laying ground area have been measured.

Spatial considerations

The installation of an underground heat exchanger requires rather large available space in the ground. In addition, a ventilation system including fans and distribution ductwork etc. is necessary.

Combination with other technologies

The underground heat exchanger can be combined with a conventional AC system, with a considerable reduction of its cooling load. Further, this technology can be combined with other passive cooling technologies such as night ventilation or can be used as a pre-stage to a heat pump.

Barriers

The installation of the systems needs to be carried out with high precision. The system has to be placed with a certain inclination, the pipes have to be installed with a guarantee of leak tightness. Filters have to be changed on regular basis. A further problem is that in some EU countries there are only few specialised companies who can install the underground heat exchanger properly. This may lead to imprecise work at the installation, which can cause problems during the operation (air tightness etc.).

3.3.9 Passive cooling systems 3: Deep Energy Sonds

In ground source heat pump systems, heat is extracted from the fluid in the ground by a geothermal heat pump and distributed to the building. The fluid is then re-warmed as it flows through the ground. The process is reversed in cooling mode. This sustainable technique can be used for cooling and heating of houses, cooling of telecommunication switchboards, etc.

The main idea of deep sonds is to use the heat that is stored in the ground and apply it to appropriate heating/cooling systems in buildings. The ground soil can be used as seasonal storage by using “earth sonds” or “energy pillars”. In earth sonds, water is pumped though pipes in the ground. Energy pillars are sonds fixed in the foundation pillars of a building.

The application of water-circulated “deep sonds” is very suitable in connection with the building mass activation. Here, the storage capacity of the water-circulated building construction parts (e.g. solid concrete covers, flooring, etc.) is put to use.

Application

Today, this technology is mainly applied on public, cultural, office and industrial buildings. The technology can be combined with conventional heating systems, temperature distribution systems (wall and floor heating), cooling components, concrete core activation or heat rejection devices.

In wintertime, earth sonds can be used to feed monovalently operated heat pumps (i.e. heat pumps as the only source of heating), which can reach an annual average COP of 5, or for passive pre-heating of inlet air.

Soils with flowing groundwater are suitable for heat extraction and cooling. Soil profiles above the groundwater or in ground with low-flowing or still groundwater store energy quite well, and therefore become easily saturated with the heat from the sonds. This energy is lost to the ground water, if its flow has a sufficient velocity. If a construction needs a foundation, it is of advantage (economically and environmentally) to apply a cooling and a heating system through energy pillars.

Performance

Specific cooling energy yield of 400 Wh/dm². Sonds with 30-50 mm diameter have a performance of about 40-60 W per running meter.

Benefits

The primary benefit is the saving of energy, that can be reduced by up to 80%.

Barriers

There is no danger of interference with the building itself due to a system with deep sonds. However, more energy than necessary should not be extracted from the ground as this could lead to a freezing of the ground and the stability of the ground could be affected.

3.3.10 Passive cooling systems 4: Groundwater and surface water systems

A further technology for sustainable cooling of buildings is the use of groundwater (aquifer) or sea/river/lake water for cooling purposes. In both cases the principle is similar – cool water (groundwater or deep sea/river/lake water) is pumped up from the “cool side” of a natural source to cool down a cooling circuit or ventilation air of a building and then is rejected back to the “warm side” of the natural source. In principle there are two similar concepts, that differ in the source of the cooling energy: Groundwater and surface water cooling.

Groundwater cooling

Groundwater systems can be used in both heating and cooling modes. During summer, cold water is taken from the “cold well” (typically at 2°C-12°C, depending on the aquifer and location) and is used via a heat exchanger for cooling the building (see Figure 6). The warm water is then recharged into the aquifer at a different location (“warm well”). The advantage of this system is that in winter the system can be reversed and warmed water (typically at 8°C-15°C) can be taken to preheat either cool ventilation air or the output of the heat exchanger may be connected to a heat pump to extend the conditioning capability of the system. A groundwater cooling system consist of two or more wells drilled in the sand bed.

It is necessary to perform accurate and specialised investigations of the aquifer and of the intended storage performance before starting to design the building. To avoid progressive heating or cooling of the aquifer, it is important that the energy input in summer and extraction in winter are approximately in balance.

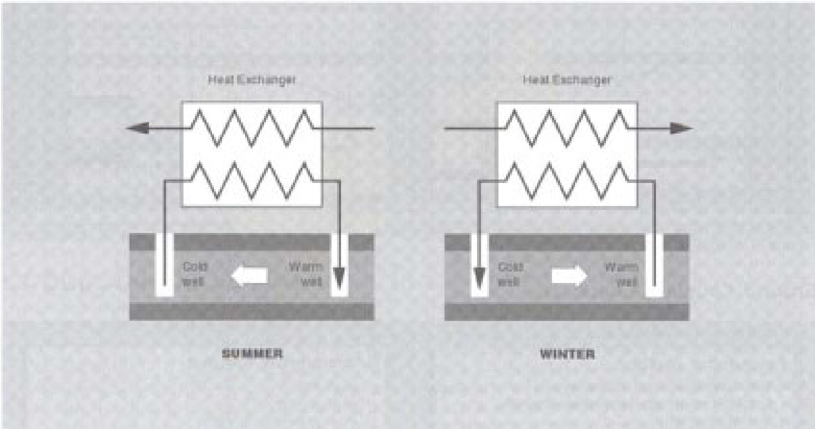

Figure 8 Using Aquifer for Cooling and Pre-Heating

Figure 6: Groundwater cooling and heating application
(Source: International Energy Agency, 2000)

Application

There are primarily two ways of applying a groundwater cooling system to meet the cooling requirements of a building: Direct cooling and a combination of direct/indirect cooling.

In the case of *direct cooling,* the water from the aquifer provides cooling to the building water loop which cools the air in the air-conditioning system or radiant elements. This system can be extended by using a chiller to supply additional cooling to the building water loop in periods of high demand.

In the case of *direct/indirect cooling*, the building water loop is pre-cooled by the groundwater storage system (direct cooling) and a chiller supplies additional cooling to the building water loop. The groundwater is also used to cool the condenser of the chiller (indirect cooling). The advantage of this arrangement is that it reduces the condenser temperature. As a result, the size of the chiller can be reduced.

Sea/river/lake cooling

Sea/river/lake cooling bases on the same principle as groundwater cooling. Cold sea/lake/river water is taken in general in an open loop in the depth of a sea/river/lake and is passed over heat exchanger to take the heat from a closed building cooling circuit. The warmed sea/river/lake water is then rejected in the surface area back to the sea/river/lake. It has to be paid attention to the corrosiveness of seawater – therefore the seawater loop may require special protection such as a titanium heat exchanger. The figure below shows the operating mode of this system:

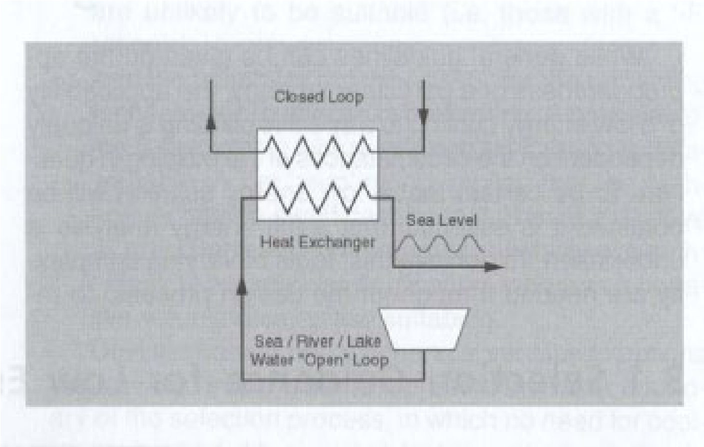

Figure 7: Lake or Sea water cooling (Source: International Energy Agency, 2000)

Application

For water temperatures <13°C an indirect cooling (condenser cooling in combination with mechanical cooling) is possible. A direct cooling in combination with a building cooling loop (ceilings, slab,…) is possible when the cold water temperature is <10°C.

3.3.11 Passive cooling systems 5: Cooling towers

There are two main applications for cooling towers: (i) cooling supply air for the building, and (ii) rejecting heat from other cooling systems, e.g. heat exchangers or mechanical cooling. This chapter deals with the last; evaporative cooling towers for cooling supply air are described in the chapter on evaporative cooling.

Cooling towers in the sense of heat rejection systems cool down water or another working medium to near-ambient temperature. With respect to the heat transfer mechanism employed, there are two types of cooling towers. *Wet cooling towers* operate on the principle of evaporation and *dry cooling towers* operate on the principle of heat transmission and convection through a surface that divides the working fluid from ambient air. In a wet cooling tower the warm water can be cooled to a temperature lower than ambient, if the ambient air is relatively dry. The design and performance of the dry cooling system is based on the ambient dry bulb temperature.

Application

Wet cooling towers are used for new or retrofit buildings. The generic term "cooling tower" is used to describe both direct (open circuit) and indirect (closed circuit) heat rejection equipment. A direct, or open-circuit cooling tower is an enclosed structure with internal means to distribute the warm water fed to it over a labyrinth-like packing or "fill". An indirect, or closed circuit cooling tower involves no direct contact of the air and the fluid, usually water or a glycol mixture, being cooled.

Dry cooling towers transfer heat to the atmosphere without the evaporative loss of water. The most common type of dry cooling towers is recirculated cooling systems with mechanical draft towers. Natural draft towers are infrequently used for installations.

Benefits

Cooling towers are in general smaller and cheaper for the same cooling load than other heat rejection systems. Typical cost indicators (relative to a conventional HVAC system):

- Investment cost - medium
- Operating cost - low
- Operating maintenance cost - low

Performance

Cooling towers may range in size from less than 20 kW for small air conditioning cooling towers to over 1.5 GW for large power plant cooling towers.

Spatial consideration

For cooling towers and for additional air conditioning systems large available space is needed for installation.

Favourable factors (Wet cooling towers)

- Installation in dry climate countries

Unfavourable factors

- Humid climate
- High quality water
- Legionella concern although risk limited by low water temperature

Combination with other technologies

- Night cooling
- Mechanical ventilation.

3.3.12 Passive cooling systems 6: Evaporative cooling

The process of evaporative cooling allows the cooling of air (incoming or exiting air) or of thermal masses (roofs, walls, ceilings). It uses the natural effect of evaporation to remove heat from the air. Sensible heat from the air is absorbed as latent heat necessary to evaporate water: warm dry air is changed to cool moist air - heat in the air is used to evaporate water. The amount of sensible heat absorbed depends on the amount of water that can be evaporated in the system.

Evaporative cooling systems can be classified in two ways. They can be *direct or indirect* according to the contact of the cooled air with the evaporated water. In addition, evaporative cooling systems can be *passive or hybrid,* according to the energy required to produce evaporation.

In direct evaporative cooling, the incoming air is in contact with the evaporated water and the water content of the cooled air increases. The *indirect* process lets water evaporate in the outlet air and transfers the cooling effect to the inlet air via a heat exchanger. This way, the water content of the cooled inlet air remains unchanged. In desert regions, where an increase of humidity is welcomed from the comfort point of view, the incoming airflow can be cooled down by direct evaporative cooling by natural airflows or even in combination with mechanical ventilation systems. In regions, where a rise of the relative humidity of inlet air is not acceptable, indirect evaporative cooling must be applied.

Passive evaporation techniques make use of the natural evaporation of water. For example, outdoor space can be cooled by passive evaporation, provided that there are surfaces of standing or moving water, such as basins or fountains. In *hybrid evaporative* systems, evaporation is controlled and/or promoted by means of some mechanical device.

Air humidification and cooling by evapotranspiration of plants and the use of free water surfaces like pools and streams, is a *passive direct technology. Passive indirect* evaporative techniques are roof sprinkling and the use of a roof pond.

3.3.13 Passive cooling systems 7: Radiative Cooling

Radiative cooling is based on the heat loss by long-wave radiation emission from a body towards another body of lower temperature, which plays the role of a heat sink. In the case of buildings the cooled body is the building surface and the heat sink is the sky - since the sky temperature is lower, especially during night, than the temperatures of most of the objects upon earth. Sky temperature during summer nights can be <0°C, with clear summer-night sky conditions even sky-temperatures of -10°C could be achieved.

Application

Two methods of radiative cooling are known for buildings. The first one is called *direct*, or *passive, radiative cooling* where the building envelope radiates towards the sky and gets cooler, thus enhancing the heat transfer out of the interior of the building.

The second method is called *hybrid radiative cooling*. In this case, a metal sheet on the roof of the building can serve as a radiator. In the cooling process, air or water is circulated under or in the radiator before it enters the building once again to cool it down with slab or ceiling cooling.

Both methods can be applied in new or retrofit buildings. For new buildings construction requirements (roof, slab cooling, static, space for cool or rain water storage) must be considered, as well as the planning of necessary technical equipment. In the case of retrofit buildings the application of this technology is only suited during a basic renovation cycle, which touches the roof as well as the technical equipment of a building.

Benefits

- Lower cooling energy costs
- Synergies and cost reduction with other applications possible → rainwater collection + cooling
- Systems with water storage can improve building's fire protection

Typical cost indicators (relative to a conventional HVAC system)

- Operating costs – low
- Operating maintenance costs – low
- Investment costs - higher

Performance

Specific cooling energy yields of between 50 and 200 Wh/m²d (roof area) are possible. In a single-storey building, this corresponds to a reduction of cooling load by less than 150 Wh/m²d (office area) or a reduction of peak loads by less than 10 W/m² (office area). In multi-storey buildings, these values must be reduced according to the number of the storeys.

Favourable Factors

- Operation in climates with dry cooling seasons
- Combination with thermal mass activation favourable

Unfavourable Factors

- Less adapted in moist and windy climates

Design requirements

- Appropriate roof construction (static, emissivity, water spraying, roof slope, etc.)
- Appropriate building design (thermal mass activation or combination with building air handling units etc.)
- Integral planning necessary
- Free view to the night sky (view factor) – probably not appropriate in high-density urban areas

Spatial considerations

Systems with (cool) water storages need extra space for large water tanks.

Combination with other technologies

- Combination of cooling system with rainwater collection system possible
- Solar thermal collectors could also be an interesting option as radiant systems
- Integration in building fire protection system

Barriers

Up to now, only a few systems are realized in case study examples. No package solution is available on the market. The application of this technology needs a specific building design by well-skilled planners.

3.3.14 Solar assisted active cooling

There are several technologies available where solar thermal can be used to drive the cooling process instead of electricity. The basic principle behind thermally driven cooling is a thermo-chemical sorption process: a liquid or gaseous substance is either attached to a solid, highly porous material (adsorption) or is taken up by a liquid or solid material (absorption).

It is distinguished between closed and open sorption processes. Closed processes include **absorption** and **adsorption** chillers. Application areas for closed systems are the production of cold water, which is either used in central ventilation stations (dehumidification) or for decentralised air conditioning, e.g. the cooling of building elements. The so-called "**desiccant and evaporative cooling system**" (DEC-system) is based on an open cooling cycle. Here, air is directly conditioned, i.e. cooled and dehumidified.

It is shown that it is necessary to reach a certain value of the solar fraction in order that a solar-assisted cooling system achieves a lower primary energy consumption than a conventional system using an electrically driven compression chiller. The system performance with regard to primary energy improves when the COP of the thermally driven chiller increases, the solar fraction increases and the specific electricity consumption of the cooling tower system decreases.

An overview of the applications and their technical data is shown in Table 2 below:

Method	Closed cycle		Open cycle
Refrigerant cycle	Closed refrigerant cycle		Refrigerant (water) is in contact with the atmosphere
Principle	Chilled water		Dehumidification of air and evaporative cooling
Phase or sorbent	solid	Liquid	solid
Typical material pairs	Water/silica gel	Water/Lithium Bromide, Ammonia/Water	Water/silica gel, water/Lithium Chloride
Market available technology	Adsorption chiller	Absorption chiller	Desiccant cooling
Typical cooling capacity (kW cold)	50-430 kW	15 kW-5 MW	20-350 kW (per module)
Typical COP	0.5-0.7	0.6-0.75 (single effect)	0.5- >1
Driving temperature	60-90°C	80-110°C	45-95°C
Solar collectors	Vacuum tubes, flat plate collectors	Vacuum tubes	Flat plate collector, solar air collectors

Table 2: Types of solar assisted cooling and their typical technical data

3.3.15 Operation and maintenance

Having followed a strategy for passive cooling, the whole building becomes to the cooling system, including the occupants. This complex system needs some understanding in order to operate well. In the following section, we outline the most important aspects as well as common mistakes and ways to avoid them.

Buildings in general

Reduce internal loads in the night, too: This way, night cooling can be more effective.

Do not open windows when outdoor air is warmer than indoor air. The fresh breeze you feel brings even more heat into the building. Moreover, the air at sun-shone façades can be very hot, because it has been heated up by the wall surface. Instead of opening windows, the fresh breeze can be produced by movable fans.

Make sure that night ventilation can take place. If air inlets and outlets do not open and close automatically, make sure that windows will be opened and closed at the appropriate time.

Instruct cleaning personnel in optimal ventilation:

- In summertime: Open windows in the evening and secure that somebody closes them in the morning again.
- In wintertime: Close all windows when leaving the rooms.
- Every season: Close all bottom-hung windows

Close the doors to the staircase. Staircases are very high indoor spaces where hot air gathers in the top. Leaving open the doors in the top floors, would allow this hot air to get into occupied rooms, where it causes heat discomfort.

Initial Monitoring

In the first time operating a complex system, monitoring its performance is of utmost importance. Only if cooling performance, energy consumption and disturbances are continuously monitored, can one detect mistakes that influence this performance.

The necessary parameters are the following:

- Operation times
- Energy consumption
- Indoor air quality (room temperature, humidity, pollution)

Already with the elimination of useless operating times one can achieve significant energy savings: Turning off the AC system during nights, weekends and holidays reduces cooling energy consumption by up to 30%. Monitoring the indoor air quality provides information about whether the system works properly or not. Displaying the energy consumption can help discover programming mistakes, as a case from Austria shows:

Austrian case study, from the EIE-project AuditAC:

A hospital installed a new cooling system. The owners decided to monitor its performance and energy consumption. After three months of operation they detected that the tolerance levels for heating and cooling were too narrow, so that the system oscillated between heating and cooling. After re-programming the system, the hospital could reduce its heating & cooling energy demand by 80%.

When operating a more complex system, the monitoring and fine-tuning in the first operation phase will be even more important. While much work can be done by simulations, the fine-tuning mostly need to take place in the practice.

Continuous monitoring

Continuous monitoring can help to detect breakdowns early and thus avoid bigger problems. In addition, it helps to optimise the energy use and detect unnecessary running time of devices.

In order to have a comprehensive monitoring, one should measure and record:

- The electric energy used by the building in intervals of 15 minutes
- The corresponding indoor comfort parameters (Temperature, humidity)

By evaluating these records, one can see what is actually happening in the building and can better understand the building services.

3.4 Selected Best Practice examples

3.4.1 Austria: MIVA Office building

Figure 8: The MIVA Building. Source: MIVA

This project is of best practice character because of the very early integrated planning process with the planning team (architectures, energy engineers, civil engineers). Lower running costs for the building were achieved and the CO_2 emissions are 80% lower than those for a conventional office building. The energy systems and the application of the building have worked in an optimal way since it was taken into operation.

The main data for the project are listed in Table 3 below:

Year of construction	2003
Type of construction	New building
Type of construction	Light outer construction with heavy inside components
Use of building	Office building including a café and loading/parking zone inside
Geographic location	48° 05' 02" northern latitude 13° 51' 50" eastern longitude, See level 370 m
Situated (city or country side)	Country side
Heating degree days	Heat: 3923 Kd (-15 °C norm data)
Main technology for heating	Deep sonds, heat pump
Main technology for cooling	Water carried systems: Deep sonds, night ventilation. Air carried systems: Hygienically air ventilation
Energy distribution	Heating and cooling panels, floor heating
Heated/cooled building area	Area = 1,215 m²

Table 3: The main data for the Best Practice Project MIVA building

The reduction of the energy demand for heating and cooling was a requirement when implementing this sustainable and also a cost efficient energy supply system. Optimisation calculations were carried out for the building and considered improvements in the U-values of the glazed areas, application of thermal building mass, reduction of glazed areas in the atrium (up to 50%), application of solar protection glass and heat protection glass, avoidance of thermal bridges, reduction of infiltration, optimised lighting concepts, optimised shading concepts, high efficient heat recovery application, application of night ventilation and optimisation of all HVAC equipment.

Since cooling demand in the building were of signification, the solution for a sustainable cooling concept played an important role. The energy supply should be both based on renewable energy sources and be cost effective.

The applied passive cooling technologies are presented in the following:

Deep sonds: The main cooling concept was the application of deep sonds. The sonds serve as both heat source (heating period) and cooling source (cooling period). The sonds are used as heat source for a heat pump (43 kW and COP = 4.03) during the heating period and are used as so-called "direct cooling". This direct cooling is realised through panels, which are flown through with cold water and integrated in the building components.

Night ventilation: This cooling concept is supported by a natural air flow through the atrium during the night. The ventilation of the office building is carried out with the means of two separated ventilation systems with heat recovery systems (78% recovery rate and 2,800 m^3/h nominal air flow) through a rotation heat exchanger. The ventilation of the seminar remises have an 86% heat recovery and a nominal air flow of 1,000 m^3/h.

Storage mass: The storage mass of the building is the stabilising element of the room temperature. The upper 10 cm in the room are decisive for this effect. 100 tons of storage mass was included in the MIVA building.

The comfort parameter indoor temperature and humidity show extraordinary good and constant values for the monitored period of two years. Also the supply during the transition time function well and almost without any auxiliary primary energy supply (heat pump). This means that the heat recovery from the ventilation system and the "direct cooling" concept with the deep sonds are enough to keep the room climate at a comfortable level. During the cooling period was the measured cooling demand 6,4 kWh/m^2a and the maximal cooling load was 11 W/m^2.

3.4.2 Austria: Bregenz Art Gallery

Figure 9: The Kunsthaus Bregenz. From left: View from the lake, backyard and the outer skin of the façade. Source: Márton Varga

The "Kunsthaus"-building was built into the existing row of solitary objects along the lakefront in Bregenz. This building is the first new museum built without a traditional air-conditioning system.

The main data for the project are listed in Table 4 below:

Year of construction	1990 - 1997
Type of construction	New building
Type of construction	Heavy concrete floors, independent double glass façade
Use of building	Art gallery, exhibitions
Geographical location	47° 30’ North, 9° 46’ East, 394 m above sea level
Situated (city or country side)	Town centre, lakeside
Heating/cooling degree days	HDD: 3470. CDD: Zurich, similar climate: ca. 100
Main technology for cooling	Load reduction measures, Building mass activation, passive groundwater coupled cooling and mechanical auxiliary cooling.
Heated/cooled building area	3,320 m² usable space

Table 4: The main data for the Best Practice Project Kunsthaus Bregenz

This project can indeed be shown as a best practice example. The building owner, architect and HVAC planners worked together to define optimal indoor climate conditions. They revisited the thermal and humidity requirements of modern art exhibitions and found out that the variations of humidity are critical, whereas variations of temperature are less important. The implemented strategies and solutions enable a very energy efficient climatisation of the building and on top of that, made even savings in the investment costs. The climate concept was flexible enough to integrate auxiliary mechanical cooling as the change of the exhibition concept made it necessary to guarantee constant temperature and humidity levels.

The building's climate system is based on the following principles:

Planning for the needs: The climate system was specially designed for the requirements of modern art exhibitions. A previous analysis showed that for modern art objects, only short-term variations of temperature and relative humidity are critical.

Solar protection: Flexible blinds are placed between the outer glass façade and the insulating glass. A daylight sensor on the roof regulates the blinds automatically according to solar radiation. The blinds rise only when no direct solar radiation has been registered for about 30 minutes. Screening out the direct solar radiation prevents an undesirable warming of the façade. The concrete parts of the façade are insulated with 15 cm pressed material.

Active coupling with the building mass for heating and cooling: A system of plastic conduits of a total length of 23.4 km was cast into the non-supporting concrete walls and into the ceilings of the building. Water in these pipes cools or heats the building, according to need. By actively coupling the room to the building mass, the storage-ability of the uncased structural mass is used to maintain a stable climate.

Low air-flow ventilation with humidity control: There are three independent ventilation systems: One for the tree exhibition floors, one for the basement and one for the ground floor (without humidifier). The outside air is gathered on three levels between the two façade layers at the east side of the building. For times of peak use, so-called “vernissage-shutters” can be opened, enhancing exhaust air flow and allowing the unused air present in the building to replace the used air. In wintertime, the outside air is heated a few degrees with the aid of heat recovery from the floors, then preheated, humidified, reheated and distributed among the floors. All floors except the ground floor are humidified. In summertime, three small refrigerating machines cool the outside air to the temperature necessary to remove enough moisture from the air. All floors are dehumidified.

Groundwater cooling: The 25 m deep slotted walls necessary for the construction are surrounded by flowing ground water. 24 km of energy absorbing pipes are integrated into these walls, linked with a 3,800 litre capacity low temperature storage tank. This storage unit feeds the circuits of the ceilings and walls of the various floors. The water, which flows back from the different floors, is mixed with freshly cooled water in a ratio of 4:1. The temperature of the ground water has a cooling function during all seasons.

Operational results showed that within the first eight years of operation, the agreed-on comfort standards were held: The indoor temperature was around 18°C in winter and mainly between 24-26°C in summer, with short term peaks up to 28°C. Humidity was between the agreed-on levels. In the "event" mode (when sensitive artwork is presented), mechanical cooling keeps temperature at constant 21°C and the ventilation keeps humidity at constant 50%, as required by the suppliers. In the "normal" mode (when modern art is presented) temperature is allowed to fluctuate by ± 3°C, and humidity is allowed to vary by ± 10%. The mechanical cooling equipment only turns on when temperature exceeds the maximum of 24°C.

3.4.3 Germany: Former barrack office-building refurbishment

Figure 10: The ebök office buildings before, during and after the refurbishment.
Source: IZES gGmbH.

The building was originally built during the 1950-ies and was used as office building by the French military and later on by German authorities. The building is under monumental protection, which had to be respected during the renovation in 2002/2003.

The project represents a successful realisation of an integral concept for rational energy use in a refurbishment situation, which relies mainly on passive cooling solutions. The project uses uncomplicated passive components such as thermal protection or the activation of thermal mass of the construction elements. Additional thermal mass was implemented for the attic lightweight construction by the use of PCM-gypsum plasterboards. The mechanical ventilation is extended from hygienic reasons to comfort improvement during summer. This is supported by the use of soil heat and cold by a brine underground heat exchanger. This heat exchanger was placed within construction and refurbishment measures, which had been necessary anyway. Very low energy consumption as well as low internal heat loads are attained by a consequent efficiency optimisation of technical installations and office equipment.

The main data for the project are summarised in Table 5 below:

Year of construction	Refurbishment 2002-2003 Former barrack office-building
Renovation	2002-2003
Type of construction	Massive structure (ground floor), Lightweight construction (attic floor)
Use of building	Office building
Geographic location	48° 30' 50,68'' northern latitude 9° 03' 16,58'' eastern latitude Sea level: 321m
Situated (city/country)	City
Heating/Cooling degree days	Heating: ca. 3,500 Kd (20/12°C) Cooling: information not available
Main technology for heating	Gas-fired condensing boiler Ventilation with heat recovery and "brine -underground heat exchanger"
Main technology for cooling	Passive means: high insulation standard reduction of external and internal loads, night ventilation, underground heat exchanger
Number of persons per building	ca. 30
Heated / Cooled building area	853 m^2

Table 5: The main data for the Best Practice Project ebök office building

Available massive, heat-storing construction (thermal mass in the ground floor) in combination with appropriate sunscreens (no exterior sunscreens due to monument conservation restrictions) led to no relevant difficulties regarding summer overheating.

The energy concept was based on a passive-house standard with energetically high efficient heat protection components (U-values of opaque components <0.2 W/(m²K), U-value windows: 0.8 W/(m²K). A high efficient ventilation system with air-to-air heat recovery via plate heat exchangers in combination with a hermetically sealed building envelope reduces uncontrolled losses or infiltrations to a minimum. The pre-heating or pre-cooling of the inlet air is realised by a brine underground heat exchanger, which is placed in the perimeter of the building. The sustainable cooling concept is based on the consequent application of passive and hybrid cooling technologies, avoiding high cooling loads as far as possible and removing remaining cooling loads only by hybrid technologies (mechanical night ventilation etc.).

The applied technologies are largely available and can be simply implemented in similar projects. The measured total energy consumption of the office building approves the planning figures. The achieved efficiency standard falls below present high efficiency bench marks of office buildings and a high efficiency standard even in a refurbishment situation.

The measured room parameters (temperature, humidity) show good working conditions with high comfort level in winter and summer.

There is a high satisfaction regarding the comfort and building climate of the employees working in the building. In summer the maximum office temperatures rose to 27°C during five days of a continuous heat period with outside temperatures of around 32°C.

The cooling load of the building is <10 W/m^2, which allows the completely passive/hybrid cooling concept. More precise values for cooling are not yet available.

3.4.4 United Kingdom: University administration building retrofit

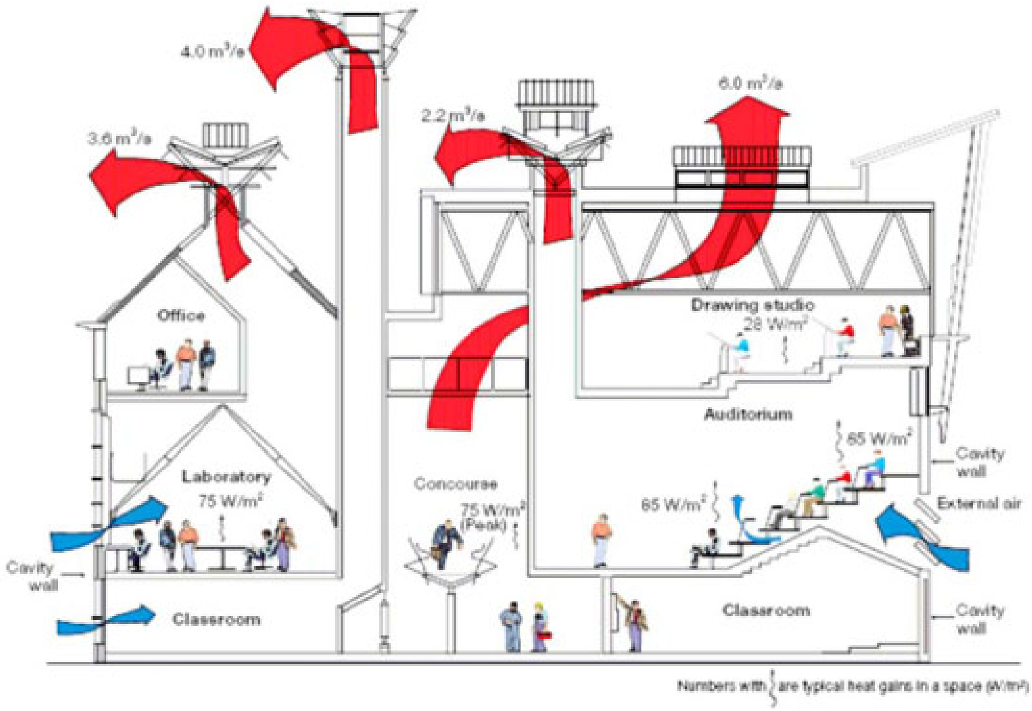

Figure 11: Scheme of the energy concept of the retrofitted university building

The University commissioned consultants to review the options for improving comfort without the use of mechanical cooling. By means of computer simulation, the periods of potential overheating were assessed for each option and the preferred design was chosen. Using modelling techniques it was found that by modifying the window system and reducing gains, comfort conditions could be maintained in all areas except the mansard roof without the use of mechanical cooling.

The main data for the project are summarised in Table 6 below:

Year of construction	1960/1970's
Type of construction	Refurbished old building
Type of construction	Heavy with lightweight extension
Use of building	University administration
Building owner	University
Building leaser/tenants	none
Geological location	52°02'N, 0°42'W
Situated (city or country side)	City
Heating/cooling degree days	1,902 (base 15.5 °C) / 389 (base 5 °C)
Main technology for cooling	Reducing gains/utilising structure as a heat sink/increased night ventilation

Table 6: The main data for the Best Practice Project UK university building retrofit

A pilot scheme was installed in selected upper-floor rooms. This involved replacing the fixed window panes with insulated panels in some rooms to halve the glazed area. Other rooms had external louvers fitted to shade all the windows. New, bottom-opening windows were fitted above and below the original centre pivot windows. These were secure so that they could be left open at night, and also had fly screens fitted.

Lighting was replaced and some equipment was relocated to reduce internal gains. Nearly half of the windows were in-filled with insulating panels. The remainder were replaced with new, opening triple glazing and high level bottom-hung windows for secure night ventilation.

An initial pilot scheme was based on modification of existing windows to allow improved, secure ventilation, and reliance of the thermal mass of the structure.

This concept was developed to lead to a further scheme involving complete window re-placement and exposure of the thermal mass of the concrete ceiling slab.

All in all, the following measures were implemented:

- A relatively small window module was chosen so that it could be installed from inside the building. This saved the cost of scaffolding, which would have been necessary if the windows had to be installed externally.
- New triple-glazed, centre-pivot timber-framed windows were installed. They had aluminium cladding for minimum exterior maintenance and high-level inward-opening bottom-hung hoppers.
- Three in every seven window spaces were in filled with highly insulated blank panels.
- Captive Venetian blinds were located in the space between the outer single-glazed pane and the inner double-glazed sealed unit of the window.
- An espagnolette locking system for the centre-pivot windows had two positions for secure night ventilation.
- Remote worm-gear control for the hopper windows provided ready access and easy operation, and meant that windows could be left open for secure night ventilation.
- Acoustic ceiling tiles-on-battens were replaced with sprayed acoustic plaster, exposing the thermal mass of the concrete ceiling slab to the room.

A range of measures help to reduce internal heat gains:

- Ceiling-mounted fluorescent lights were replaced with free-standing compact fluorescent uplighters with electronic ballasts; and individual on/off and high/low levels improved choice with less energy consumption.
- Switch controls were fitted which allowed all lights to be switched off from the exit doors, but only the corridor lights to be switched on again from this position. All other lights are switched locally.
- GLS tungsten task lighting was replaced with fluorescent task lights.
- The shared laser printers were grouped with an extractor hood above, permitting warm air and fumes rising from the units to be drawn from the office.
- The photocopier was placed in an independent room with an extractor fan. This was also recommended by the University’s ergonomics advisers.

The results of the retrofit was shown in a reduction in peak temperatures from 28°C to 26°C was enough to keep staff comfortable.

For the design studio the new measures were predicted to reduce peak temperatures by 4°C, even after moving equipment, and rarely exceed 27°C, a typical target for natural ventilation. In practice, peak internal temperatures do remain below peak outside temperatures. Even though internal gains are higher, and thermal mass is lower, the studio is typically 2°C cooler during the day and 4°C cooler overnight than on the floor above.

The refurbished areas require no mechanical cooling, saving about 30-45 kWh/m²a compared to the mansard roof area in the building.

Staff was involved throughout the design process, in the layout of the windows, the type of lighting and even the furniture. The sense of involvement was important in giving a feeling of control over the workplace.

This scheme shows how the installation of comfort cooling can be minimised by making use of the existing building elements and by modifications designed to enhance the effectiveness of these as a heat sink. It also demonstrates measures to minimise the requirement for cooling by limiting heat gains to the building and maximising ventilation.

3.4.5 Sweden: Office Building Garnisonen

The purpose of this project was to study if a combination of passive measures in an office building can be enough to reach summer comfort and it could be shown that in a normal office building in Stockholm, it is possible to meet the needs for summer comfort without active cooling.

Figure 12: The Garnisonen building

The building is from around 1890 and is a brick-building. Windows facing east and south have awnings and blinds (between windows). During hot period is the night ventilation with max flow rate used as long as the outdoor temperature is lower than the indoor temperature. Normally, the outdoor temperature in Sweden in July is more than 10°C lower than the indoor temperature at night.

The main data for the project are summarised in Table 7 below:

Year of construction	About 1890
Refurbishment	Test period to run the building without active cooling
Type of construction	Heavy
Use of building	Office
Heated building area	Ca. 350 m²

Table 7: The main data for the Best Practice Project Garnisonen

The following concepts to reach summer comfort were implemented:

Awnings and blinds: Windows facing east and south have blinds and awnings. The blinds are not used so frequently, so the total reduction of the radiation from the sun is about 80%.

Lighting: Installed power for lighting is about 10 W/m² in the offices and about 8 W/m² in other areas.

"Open doors": The office rooms are situated along the walls facing north, east and south. The rooms are 1 person-rooms. It is important that the doors to the corridors are open to help the transport of heat from the rooms. As a comparison room temperature in a room (facing south) with open door were measured, and a room (facing east) with closed door. The room temperature in the room with closed door was up to 1°C higher than in the other room.

The results are expressed with the Swedish recommendation "P25", which was achieved. "P25" means that indoor (operative) temperature are allowed to exceed 25°C 10% of the working hours, considering statistic outdoor temperature during a July-month.

3.4.6 Portugal: Edificio Solar XXI

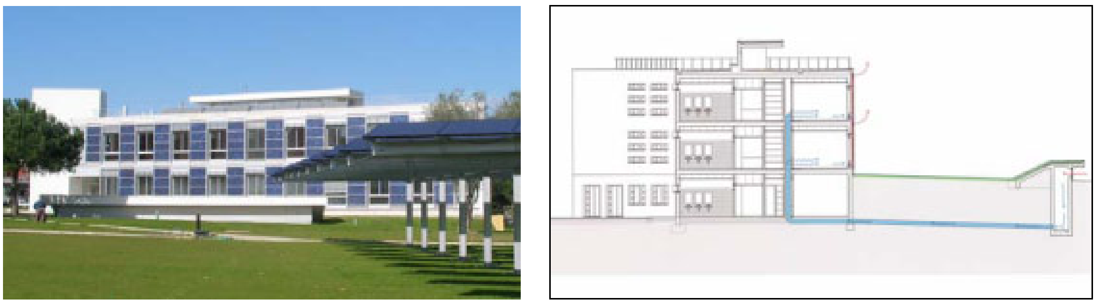

Figure 13: *Edifício Solar XXI*: South façade and scheme of ground cooling. Source: INETI

The building is located inside the INETI campus in Lisbon and it is the new office premises for the Renewable Energy Department of INETI. "Edifício Solar XXI" shall operate comfortably as an office building, while being a demonstration project for building solar passive and active technologies. The building has about 1500 m² split by three floors, one of them lying underground in the South façade, with office rooms, meeting rooms and laboratories.

The main data for the project are summarised in Table 8 below.

Year of construction	2004-2005
Type of construction	New building, Heavy, concrete structure and brick walls
Use of building	Office building
Building owner	INETI - National Institute for or Engineering, Technology and Innovation
Architect	Pedro Cabrito & Isabel Diniz (Project coordination: Hélder Gonçalves)
HVAC designer	Marcos Nogueira
Location/address	Estrada do Paço do Lumiar 22, Lisboa
Geographical location	38° 460’ North, 9° 10’ West
Situated (city or country side)	City
Heating/cooling degree days	1190 HDD (base 20 ˚C) CDD n.a. (design outdoor temperature: 32 ˚C)
Main technology for cooling	Underground earth ventilation, Ventilated façade, Natural Ventilation, Building mass activation.
Heated/cooled building area	1500 m²

Table 8: The main data for the Best Practice Project INETI building

This project shows that it is possible for a building office located in Lisbon (Mediterranean climate) to meet the summer comfort needs without active cooling systems. Technologies used for passive cooling addresses the main techniques available: sun protection, thermal mass, individual adaptation, earth cooling, ventilated façade and natural ventilation. It is also shows a remarkable integration of sustainable technologies like solar passive heating, passive cooling and active solar thermal and solar photovoltaic systems.

Passive cooling strategies in the “Edifício Solar XXI” building avoided the need to install a mechanical cooling system. These strategies are described as follows:

- Optimisation of the building envelope: Externally applied thermal insulation (U-value façade: 0,5 W/m²K, roof: 0,3 W/m²K) avoids thermal bridges and allows the thermal use of the building mass. Double glazing with external movable Venetian blinds (solar factor of 0,04). With these measures, heat gains through opaque façades and roof are (i) reduced, (ii) stored in the mass of the building and (iii) released during the night to indoor spaces that can be sufficiently cooled down by natural ventilation.
- Reduction of internal heat loads by extended daylight use: In the central part of the building, there is a skylight that harnesses natural lighting for the three floors, as there are transparent elements between central corridor and adjacent rooms;
- Natural ventilation: two main techniques were applied:
  - Ventilated façade: using the heat generated in the rear part of the photovoltaic panels, operating together with two openings in each room (at low and high height) to create a free convection air movement in the South façade;
  - Stack effect: there are openings in the skylight and in the other parts of the building façade, to allow the night cooling ventilation;
- Earth to air heat exchangers: consists of 32 concrete buried pipes, 4,6 m underground, with 30 cm of diameter each, having a buried plenum 15 m away of the south façade of the building. The pipes take the outside air, cool it down, and conduct it into the building by a vertical distribution system (open “fresh air” system). In each room, there is an en-

trance for two pipes, that can be manually regulated, and a small fan for increasing the incoming air flow rate. This system can "explore" the temperature difference between outside air (in summer it can reach 30-35 ˚C) and soil (14-18 ˚C).

- Individual adaptation: users are allowed to change their clothes, to open or close windows and doors, to regulate the position of the Venetian blind and to regulate the air flow rate coming into their room from the earth tubes.

3.5 Toolkit

In total, the KeepCool project team described 14 Best Practice Projects in English and 41 in national languages (German, Lithuanian and Spanish). All Best Practice Projects, as well as detailed technology profiles, an analysis of the national comfort legislation, lists of experts and suppliers of passive cooling technologies in the participating countries and additional information material has been processed into an online toolkit for building owners and other target groups (see Figure 14).

This toolkit is not only a new resource base for passive cooling. It combines our approach for sustainable summer comfort with the complex set of roles the different actors take when constructing, using, operating or maintaining a building. Beside the general information, the main target groups Building Owners, Building Users, Operation and Maintenance (O&M) Staff and Technical Consultants are linked to those steps which are in their own competence.

Figure 14: The KeepCool Toolkit, online at www.keepcool.info

4 Marketing and dissemination for sustainable summer comfort

4.1 Introduction

In order to achieve real change of construction practice, marketing activities must go beyond pure dissemination and information transfer. They must include also activities related to ”market transformation” by bringing together the relevant actors and building up a structured supplier/customer dialogue in the scattered market of passive cooling.

The main dissemination activity in the project was therefore direct advice to building owners and the other target groups. In five countries, this advice resulted in pilot projects in both new construction and refurbishment that will apply our approach of sustainable summer comfort. In three countries, we conducted architecture competitions, and two countries worked with the suppliers of sustainable comfort solutions, providing a meeting point to start cooperation. Beside direct advice, awareness building activities were conducted in all participating countries. The project team organised workshops, and was present at events and fairs of the target groups. In addition, we were present in daily and specialised media, and built up several websites in English and in national languages.

In the following sections, the dissemination activities of selected countries are reviewed in detail. In addition, four of the pilot projects are described.

4.2 Review on the dissemination activities in selected countries

4.2.1 Austria

In Austria, there is a growing number of demonstration projects with low energy buildings both in the residential and in the service buildings sector, and their construction is enhanced by various governmental programmes (klima:aktiv, Haus der Zukunft, regional programmes). However, most of these programmes concentrate on heating energy demand, and have paid little attention on the summer case. In the broad construction market, the standard way to deal with summer comfort is still to install air conditioning. Although interest in building energy issues has constantly increased in the last years, usually property developers have very little knowledge about summertime energy consumption, passive cooling technologies.

KeepCool is integral part of the klima:aktiv programme ecofacility, the Austrian Climate Protection Programme for energy efficient modernisation of service buildings. Managed by the Austrian Energy Agency, this programme built up a network of building energy advisers, developed standardised advice modules from a cost-free benchmarking up to comprehensive management information for the decision on the modernisation measures, including technical, financial, organisational and legal analysis. At the beginning of the year 2007, ecofacility has a stable network of 40 building energy advisers, covering all Austrian regions, mostly organised in regional sub-networks. In total, around 500 benchmarks of buildings and

340 comprehensive advice packages with recommendations for modernisation measures have been made since the start of these activities early 2005.

The second main activity of the programme is marketing and dissemination of energy efficiency in buildings, delivering new modernisation projects to be given advice by the advisers network. ecofacility had numerous appearances in the daily and specialist press, and was presented in a large number numerous events for specific target groups: real estate companies, facility managers, hotel owners, etc. ecofacility was presented internationally at the IEECB´06 Conference (Grim, 2006). Up to date information on the programme (in German language) can be found at the website www.ecofacility.at.

The input of KeepCool on summer comfort and passive cooling technologies was well recognised within the ecofacility advisers network. KeepCool helped to design a new advice package for the new construction of service buildings. This new package integrates energy efficiency requirements in the summer and the winter cases, providing advice modules for each stage of the planning procedure, from helping the building owner to define energetic quality goals prior to any planning, up to a comprehensive building simulation with recommendations for improvements in the detail planning. The KeepCool toolkit provided the model for a similar toolkit in the German language on energy efficiency in the planning and construction of buildings. Many of the Best Practise examples were translated into German and used in ecofacility. This way, the KeepCool results will form an integral part of the future advice activities of the ecofacility programme.

The project succeeded to raise public attention, too: After the first year of the projects, newspapers started to ask for information. In total, 9 articles were published focusing on summertime energy efficiency, passive cooling and summer comfort. One technical magazine even printed the local KeepCool website as an article. ecofacility and the KeepCool staff was also co-organising the Austrian State Award for Architecture and Sustainability, and included sustainable summer comfort into the evaluation criteria of the service buildings category. The public interest is persisting even after the end of KeepCool project: One of the main daily newspapers made an interview with the project coordinator and published an article on summertime energy consumption and the EPBD.

4.2.2 Germany

In Germany, the market for sustainable cooling is a subject of growing interest for experts. In the context of a public funding programme named “SolarBau”, several case studies of energy efficient office buildings were realised. However, in general there is no large market penetration of “sustainably cooled” building concepts, outside some case study activities: there are approximately 100 realised projects in Germany, but the standard planning provides in general a conventional cooled building. Some passive cooling methodologies (sun protection, glazing, thermal mass, night ventilation rate) are implemented in the existing standards in a simple verification procedure, but still there is a large gap towards the philosophy of sustainable summer comfort. Therefore, up to now sustainable cooling and integral planning have been a market-niche.

In order to increase the broad awareness for sustainable cooling, the German dissemination activities of KeepCool concentrated on events with great multiplication potential. Among others, the project organised an architecture competition for “Sustainable Cooling”, with an awards session in the Berlin Energy Days 2006. The competition was accompanied by a media campaign in the technical press and German online information services. In total, 18 high quality applications were submitted, from which a jury of renowned German experts selected the three best projects. The media and dissemination campaign reached a broad mass and allowed a lot of contacts with experts, planners, building owners etc. The feedback during and after the competition award showed a high interest for sustainable cooling.

Parallel to these activities, KeepCool set up a comprehensive German language information website on sustainable cooling, within the frame of the commercial online info line www.baunetz.de (More than 150.000 registered users, 75% of them being architects and planners). The direct URL to the German Keep Cool homepage is www.keep-cool.net. In total more than 140.000 hits could be registered from August 2005 to February 2007. The website provides not only short technology profiles from the most important steps to achieve sustainable summer comfort, but is also an information point for German events in this sector, including reports and Best Practice examples from the architecture competition, contact details of suppliers and experts in the field of sustainable cooling, and a link to the KeepCool Toolkit. In an adapted version, the German technology profiles were also published in the Austrian online encyclopaedia www.energytech.at.

Exemplary, among a lot of others, these two measures allowed to reach a broad mass and to raise the awareness of our target groups. The number of more than 140.000 hits of our web page shows the feedback and we hope that we could start indirect effects with our information campaign as well as with the knowledge transfer.

Beside these broad market oriented activities we provided direct advice to planners, architects, building owners and tenants in a lot of individual contacts in the subject of energy efficient construction and sustainable cooling. Beside direct and telephone consultations, seminaries and other events, we used the KeepCool material to provide advice to building owners/tenants concerning sustainable cooling strategies in two different projects. In one case the refurbishment of an existing 70’s office building was envisaged, in the other a new construction was planned. In the first case (refurbishment) the consultation-process had to be cancelled after a promising beginning, because of the future tenant decided to rent a new building, so that the building owner stopped the refurbishment activities. In the second project we are on a good way and the consultation process is going on after the end of the project (for more details on this project, see section 4.3 below).

The direct contacts with the target groups showed different barriers in the traditional planning processes:

- Sustainable cooling is always an integral approach, and this makes its promotion much more difficult than the air-conditioning (AC). The conventional AC-technologies have a powerful industry lobby, whereas sustainable cooling means the cooperation and promotion of multiple technologies with different suppliers.
- The integral approach is more laborious and time-consuming in the planning process, which generally means higher panning costs. What is happening is the contrary: Sometimes even the most basic rules are neglected in the early phase of planning, because of simple lack of time.

- Often, building owners, tenants (and sometimes the planners, too) do not even see the necessity of an integral approach for a sustainable cooling concept. In general, they do not know/understand these concepts – and often, they are suspicious against new ideas.
- Planners/architects fear to investigate in new technologies and to deviate from conventional experience. In general they favour traditional planning procedures- as they are mediators to the building owners/tenants often new concepts are not applied.
- Financial incentives/benefits have to pave the way towards a more energy efficient and sustainable building planning. A regular point in the discussions with building owners was the question whether the KeepCool project could provide financial subsidies. Without political and economic incentives this market will most probably stay a niche-market.

4.2.3 Italy

Italy is responsible for 25% of the European AC market (Adnot et al., 2003). However, the hot climatic conditions make the realisation of passive buildings a task which needs careful design. A few industrial actors are trying to promote their energy-efficient products, but up to now they have mostly focused on winter comfort and consumption and acoustic comfort. Similarly, there is only a small number of examples of recent buildings built explicitly with the aim of achieving low energy summer comfort and little monitoring documentation is available.

Here, our activities concentrated on the education of a new generation of architects and engineers who should be made aware of the potential of envelope and passive technologies to reduce the cooling loads and improve comfort. They also need to know the physical and calculation basis for defining a low energy concept, sizing the main variables, calculating energy and economic performances with different tools at different stages of the design process.

The KeepCool strategy for sustainable summer comfort (see sections 3.1 above), and selected envelope and passive technologies were included into a number of university courses for architecture and building engineering students at the universities of Lecco and Milano and at the Master course on Energy Efficiency, Renewables and Local Energy Planning (RIDEF), and into the Building Physics courses to candidate building engineers in Academic year 2004/2005 and 2005/2006 (The Building Physics course runs from March to June, consists of about 100 hours lectures and practical calculation, involves around 200 students per year, is taught since 2004 by Pagliano and two assistants). Lectures and practical calculations have given during these two years a special emphasis on:

- ways of improving the thermal performances of the envelope in winter and summer (e.g. effects of thermal mass in limiting temperature swings and as an element of night ventilation, insulation effects on cooling load, solar factor of glazing and shading devices)
- achieving high efficiency lighting and daylighting, in order to both reduce direct consumption and summer cooling load
- designing after having clearly and explicitly defined the comfort objectives to be achieved within the building, taking duly into account the two main models of comfort (Fanger and Adaptive), as they are included in EN 15251.

The Lectures at the University of Lecco in 2006 were part of a Integrated Design laboratory for students of the 5th year of the Architecture-Engineering Faculty in Lecco (course runs from March to June, the envelope and passive technology section consists of about 15 hours lectures and practical calculation, involves around 20 students per year, was taught in 2006 by Pagliano and two assistants). The Laboratory is aimed at guiding the students in the design of a building or complex of buildings which will be the basis for their final graduation exam. It involves many disciplines and our role was to bring into the process up-to-date knowledge about envelope and passive cooling technologies, showing case studies, etc. The materials developed for KeepCool proved to be useful teaching tools.

At the Master Course RIDEF, which is attended by engineers, architects, economists, energy policy analysts, both neograduate and with years of work experience, aims at creating professionals with an integrated view on technologies for efficiency and renewables, policy mechanisms, promotion and diffusion projects, energy planning. They typically work in energy companies, ESCOs, renewables companies, local governments etc. to design and implement programmes and projects for efficiency and renewables. Approximately 40 people graduated in each year 2005 and 2006, and most of them are now working in the field of efficiency and renewables. They were given lectures on envelope technologies and passive cooling technologies. Some of them are actually working now to develop low energy cooling projects (envelope, shading, ground cooling). In this course, too, the materials developed for KeepCool proved to be useful teaching tools.

In addition, KeepCool was present on the media in Italy in order to sensitise the broad population to the necessity and the advantages of passive cooling measures, of good practices for controlling locally the thermal environment (use of windows, shading devices and ceiling fans, choice of chairs and dressing code). Beside numerous appearances in daily press, KeepCool has appeared on radio and TV broadcasts. Finally, the project has promoted sustainable summer comfort and passive and envelope technologies at a high political level (see section 5.3 below).

4.2.4 Lithuania

In Lithuania, construction of public buildings expands every year. In year 2005 in Lithuania their area comprised 1,3 million m². It may be stated that most part of contemporary buildings during summer is cooled. Only active cooling facilities are used for this purpose. Energy consumption is large since employees of institutions try to preserve comfort conditions during summer. Passive cooling conceptions are known, but practically not implemented in Lithuanian buildings.

The main actor in the initial design process of a building is the building owner. He is the one who presents a vision regarding his building, which is implemented by designers of many fields. In this stage, consultants of efficient energy use should be more active, spreading all available information on the possibilities and benefit of sustainable cooling.

By participating in KeepCool project, employees of the Lithuanian Energy Institute gained knowledge how to implement the ideas of passive cooling. LEI translated 7 “best practice projects” into Lithuanian, one from each country participating in the project. Translated best practice projects help best to comprehend that passive cooling ideas are implemented in different countries of European Union, and the similarities and differences to Lithuanian conditions. Each project had the following sections: main data, architectural conception, energy conception, operational results, building and operational costs of project, description of implementation process, justification why this project is good. Economical calculation presented in the projects revealed how much energy had been consumed for heating and cooling. Sometimes these numbers were very impressive for Lithuanian building owners and designers. We also translated 8 technology profiles from the KeepCool toolkit into Lithuanian, which are recommended to be used in order to implement passive cooling ideas. The suggested tools are known in Lithuania, but the application of their sequence is an impulse towards the implementation of sustainable cooling idea. Flyers, "best practice projects" and "available solutions for sustainable cooling" comprises 95 pages of translated text.

During project implementation we published two articles in which we had analysed the ideas of sustainable summer comfort. One of them can be found in the journal "Thermal Technology" (600 copies), the other one in a journal called "New Construction", which is frequently read by architects and designers, (4500 copies).

"Face to face" meetings with sellers, designers, house owners of air conditioning facilities enabled to directly cooperate with key actors and explain to them the peculiarities of buildings passive cooling. They were also invited to various meetings, however, they rarely visited. Cooperating with seminar participants we noticed that after the seminar, discussed ideas were still vivid, seminar participants requested for additional literature, which we could provide with the material we had translate into Lithuanian. Other information was placed on the internet.

It should be stated that a great amount of time was required to handle new information, write articles, translate information into Lithuanian, and organize seminars, whereas the project time already has expired. We are confident that spread of passive cooling ideas will not cease in the future since its realization would enable to save Lithuanian energy input and develop comfort conditions in buildings.

4.2.5 Portugal

In Portugal, the existing market for "sustainable cooling" is very small. A very small number of passively cooled buildings exist. The main reasons behind their existence are the demonstration technology approach or the environmental marketing benefits for the respective promoters/building owners. External shading is avoided by architects in many tertiary buildings for aesthetical reasons. Air conditioning equipment sales are growing fast. The European Building Performance Directive is only partly in force.

Here, KeepCool's goal was to increase awareness within selected target groups, especially for building owners. This was achieved by organising and participating in meetings and workshops, and by direct advice to building owners in individual meetings. The point of this advice was to show that sustainable cooling can be achieved today, with the help of the toolkit and of the Best Practice Example from INETI (see section 3.4.6 above) and from other countries.

Besides building owners, other specific groups or institutions were targeted in order to be aware of KeepCool results: architects, HVAC designers and their associations, building managers, private consultants in the fields of energy, environment and certification, the National Energy Agency ADENE, the Portuguese Business Council for Sustainable Development BCSD Portugal, among others. In cooperation with BCSD Portugal, five workshops have been held dealing with energy efficiency, which gave a good opportunity to disseminate the KeepCool results.

Personal contacts in meetings or in workshops was the main approach to influence these target groups and increase their awareness about sustainable cooling solutions. It is estimated that the total number of persons reached by this way is close to two hundred people. Some of them showed interest in KeepCool results, establishing then a link to CEEETA, in order to get advice about sustainable cooling and other sustainable energy issues.

Despite some potentially interesting situations, pilot projects involving new buildings or retrofit of existing buildings, have been not initiated during the two years project duration of KeepCool. However, at the closing time of KeepCool project, new developments have promised, for the near future, more building candidates for the application of “our” sustainable summer comfort methodology and the related technologies, being this a successful outcome of KeepCool. Concerning existing buildings, energy audits campaigns led to the study and recommendation of a set measures, some of them aimed at achieving sustainable cooling solutions. In a specific case in a building office in Guimarães, reduction of internal heat loads from lighting and computers was recommended as well as the improvement of the external solar shading system.

The dissemination of the KeepCool toolkit reveals that users usually prefer the software stored in the CD instead of using the same software, not downloadable, trough the website. However, this finding puts some difficulties in toolkit development process, which can always be improved and augmented: nobody wants a CD with a software version that may be outdated in the next day. That’s why our emphasis for dissemination activities, during the process of developing the toolkit, has been directed to use more the website and less CD copies.

4.2.6 Scotland

In Scotland, there is continued support for improving the sustainability of buildings from the legislative aspect of Governmental activity. The demand for air conditioning is still low compared to other countries, but desire for controllable climate conditions in the working environment is increasing. There is a general understanding of the concept of sustainable cooling, but there is a reluctance to consider its integration into projects because cooling is regarded as a relatively low cost aspect of the building life cycle costs. The continuation of the pressure to increase the percentage of renewable energy which is to be supplied to new and refurbished buildings will encourage the greater utilisation of sustainable cooling. There is still a need to promote the concept of sustainable cooling into the general building user audience to increase the pressure on the building owners. Building regulation changes are creating the pressure for change.

It has been necessary to try to increase the understanding of the relevance of sustainable cooling into an audience which does not consider this concept in the forefront of their consideration of building sustainability. There has been an attempt made to include existing bodies into the process of publicising and encouraging the use of sustainable cooling within the education of professional individuals involved in the design, construction and installation of building and their control systems. However, the economic pressures of the other aspects of the building control has meant that the more traditional methods of providing cooling comfort are still the predominant concepts that are considered.

Contact has been maintained with Scottish Executive with one article provided for inclusion on their website and a further article which has been written for publication in a sector specific magazine. The KeepCool information has been included on the NIFES website.

The presentation of the KeepCool concept at SEEC in February 2007 did receive attention from the attendees, although the application of biomass heating was a topic which received greater attention. This exhibition gave the opportunity to present the sustainability concept to an audience where its application was already important. The audience of predominantly building users and specifiers were interested but not enthusiastic about the concept, although there were a number of discussions about its possible use in educational establishments.

There was a stand commissioned at SEEC conference which had an attendance of 305 people whose backgrounds covered local authorities, commercial and industrial organisations. There were 25 CDs issued to interested parties at this conference. Face to face discussion about the subject has proved to be difficult except in this conference environment. With the difficulty in organising face to face discussions, telephone contact was made with 97 architects who agreed to receive the CD and were also given the website address.

Consideration of the KeepCool philosophy was incorporated into the conceptual design of a commercial retail outlet, although construction and progression of this sustainable concept has currently been put on hold by the organisation.

4.2.7 Spain

Traditionally, in Spain, energy consumption in buildings is not taken into account, but little by little, the attitude towards the sector has been changing. Although the transition process is slow, the Spanish administration at both national and regional level is trying to bring about change by means of norms/standards for buildings of new construction and through economic incentives for existing buildings. The basic requirements (HE 1) of the Technical Building Code, which is the result of the transposition of the articles 4, 5 and 6 of the European Directive 2002/91/EC, the Royal Decree 47/2007, of 19th January which approves the Royal Decree 47/2007 on the Basic Procedure for the energy efficiency certification of new building constructions, result of the transposition of the Directive 2002/91/EC and the Andalusian Regional Government is to approve shortly the Law of the Promotion of Renewable Energies and Energy Saving (which obliges newly constructed buildings in Andalusia to have a minimum energy assessment).

The KeepCool project was a good complement to these political efforts, helping to convey the message of energy efficiency to the market actors in the building sector. The dissemination activities in Spain included meetings and telephone conferences with agents in the design, construction, maintenance and operation of buildings and their installations. Contacts were made to two architecture schools, two new headquarters of architect associations, three engineering schools, two engineering associations, ten constructors and promoters of buildings associations, seven maintenance companies and four installer companies. In addition, a number of the KeepCool reports were translated into Spanish language and given to the different agents from the sector. These documents were also used to develop an exhibition on sustainable summer comfort.

The insights gained in KeepCool influenced the “Competition of Ideas (Preliminary Plans) for the definition of the Headquarters Building of the Andalusian Energy Agency”. The object of this open competition of architectural ideas was defined, in a Preliminary Plan stage, through its sustainable architecture characteristics. The selected building includes energy efficiency, innovative materials, new technologies and renewable energy systems, and, of course, adequate means to support sustainable summer comfort.

The follow-up of the project considers many of the steps for achieving a reduction of energy consumption in buildings, both by the reduction of the energy demand as well as by the improvement of the efficiency of the installations. The Andalusian Energy Agency is planning to organise information days in the year 2007, where people will be given information how to reduce the energy consumption in buildings to fulfil the new norm (CTE) and also to obtain savings in their energy bills. The concept of sustainable summer comfort will certainly be presented at these info days.

4.2.8 Sweden

Despite the cold Swedish climate, the installation and use of mechanical cooling has become a standard practice in commercial and office buildings. Cooling is emerging even in the residential sector, namely through the increasingly common use of reversible heat-pumps. A barrier for the penetration of sustainable cooling is the way the two industries – air conditioning industry and the sustainable cooling industry – are organised. The air conditioning industry is a mature industry and the process for the building owner to follow involves only few actors. Conversely, sustainable cooling solutions, even if they often require simple technology or even non-technological procedures, are provided by a very scattered industry, thus requiring the involvement of several actors.

The project KeepCool has addressed this barrier by bringing together the relevant market actors and building up a structured supplier-customer dialogue. On the supply side of sustainable cooling solutions, a group was set up aiming at offering a packaged solution for sustainable cooling. This group was composed of actors that (1) address reducing internal loads (through industrial trade associations for lighting and for IT equipment), (2) that provide passive cooling solutions (through the association of blinders and shutters), and (3) that provide integrated services like entrepreneurs and energy service companies. Strategies on how to offer packaged summer comfort solutions and how to market them to building owners were formulated.

On the demand side, i.e. the building owners, the approach included a range of seminars and dialogue sessions where building owners could meet the participants in the sustainable cooling solutions supply group above mentioned to discuss the possibilities of avoiding or reducing the need for compressor-based air conditioning. Another type of activities organised was through face-to-face meetings with large building owners for discussing pilot projects and the adoption of guidelines for a sustainable provision of summer comfort. This has been facilitated by a collaboration with the network of commercial buildings buyers group, which is animated by the Swedish Energy Agency.

4.2.9 International Dissemination

Since the target groups of the project are mostly organised nationally, international dissemination was of secondary importance. Nevertheless, international meetings were a good concentration point to scrutinise the KeepCool approach to Sustainable Summer Comfort.

The project or specific parts were presented and discussed at the following international conferences: At the 9. International Passive House Conference 2005 (oral presentation), at PALENC 2005 (Pagliano & Zangheri, 2005), eceee 2005 (informal session on summer comfort), IEECB 2006 (Varga & Pagliano, 2006), NCEUB 2006 (informal discussions) and finally with three presentations at EPIC 2006 (Varga et al., 2006; Nicol & Pagliano, 2006; one additional oral presentation). Parallel to these activities, KeepCool was invited to an expert meeting of the WHO, and was briefly presented by the AuditAC project team at the AICARR 2006 Conference.

During these activities, KeepCool and its findings got a broad international audience. Even companies which are not usually dealing with such issues, became aware of summertime energy efficiency in buildings: So, for example, McKinsey, who detected KeepCool within the papers of the IEECB'06 conference and conducted a long interview with the coordinator in order to include sustainable summer comfort into the internal guidelines they were developing at this time.

The international meetings provided opportunity to develop KeepCool's interventions to the EN 15251 "Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics", both in getting contact to and the support from Prof. Fergus Nicol, the founder of the Adaptive Comfort Model, and in discussing our suggestions directly with the authors of the proposed standard at the side of various meetings.

Follow-up activities are also scheduled: The results of KeepCool will be presented at the eceee 2007 Summer Study (Lopes, Nicol, Pagliano & Varga, 2007), and the project got an invitation to the PALENC 2007 conference.

4.3 Selected pilot projects

4.3.1 Vienna: Refurbishment of a 70-s office building

Type of building

Centrally air-conditioned 70-s office building, 4000 m², very low insulated building envelope, only internal shadings, over-dimensioned ventilation system, high energy consumption both for heating and cooling.

Figure 15: Outside view of the building

Actions taken

1. First raw analysis of the building energy consumption, and benchmarking with other office buildings
2. Detail analysis of the building and its HVAC systems, and development of management information for the building owner with recommendations for refurbishment
3. Offer to develop a concrete refurbishment plan in cooperation with an architect, and offer of EPC tender management for the HVAC technology.

Measures recommended

- Energy and internal heat load savings with the office equipment: Power management measures and complete equipment with efficient office equipment (lighting is OK already)
- Comprehensive refurbishment of the building envelope, with three variants:
  1. Exchange of windows, and installation of external shading (15-20 % savings).
  2. Second façade around the building, with external shading and roof insulation (ca. 50-60% savings).
  3. Complete new double façade with shading elements in between and roof insulation (ca. 50-60% savings and new image of the building).
- Energy Performance Contracting with the HVAC systems, including:
  - Adaptation of the HVAC systems of the new requirements after the refurbishment, or (in case of no refurbishment)
  - Volume-controlled ventilation, strong reduction of the air movement, reduction of running hours and reduction of air treatment.
  - Exchange of the chiller.
- User motivation, temperature monitoring, right ventilation behaviour

Short history

In December 2005, the owner approached the Austrian Energy Agency with the request of an energy analysis. A first rough energy check (based on annual consumption of heat and electricity) resulted in a very high savings potential. On the base of these results, and in the framework of the national climate program ecofacility, the Austrian Energy Agency prepared a detailed management information paper for the building owner, containing an analysis of the building, the patterns of electricity consumption, and measures to decrease heating and cooling energy demand. The results were presented in April 2006 to the building owner. As a result, the owner asked the Austrian Energy Agency and an architect – expert for energy efficient building refurbishment – to offer a comprehensive refurbishment plan for the building envelope and an EPC tender for the HVAC technology. These offers were submitted in June 2006. After a long silence we learned that the building owner has made and follows an own refurbishment plan, which only partly takes into account the proposed measures.

Influence of KeepCool in this pilot project

The state-of-the-art reports of summer comfort are the summer case additions to the standard ecofacility consultation process. Without them, the recommendations would have focused on the winter case. Especially shadings, the chiller and internal heat loads would not have been included into the energy saving recommendations.

4.3.2 Germany: New construction of an office-/industrial-building in Augsburg

Building Owner

Klimashop, Augsburg

Type of building

Planning of a new office-/industrial building. The manager of an enterprise, who sells and installs devices for air conditioning plans to build a new building for its enterprise. The building should be an office building for the administration,… as well as factory and stock for the craftsmen.

Actions taken

1. Presentation of the whole range of sustainable cooling using our toolkit within the Otti-Seminary “Cooling of office buildings”.

2. The manager of Klimashop contacted us a few weeks later. The building owner, who is working in the field of air conditioning, showed interest for the application and demonstration of sustainable cooling concepts in its planned building.

3. In the following weeks first plans/sketches were exchanged, general advices for the design of the building were given.

Figure 16: Sketches of the Klimashop Building in Augsburg, Germany

Measures recommended

Different measures as described below were generally presented:

- High insulation standard, controlled ventilation
- Information about user behaviour, summer comfort
- Reducing of external loads by external shadings, limiting the window at the necessary level
- Reducing of internal loads
- Presentation of sustainable cooling strategies like night ventilation, earth ground heat exchanger, solar cooling etc.

Short history

In January 2007, we had a new promising contact, as a result of our KeepCool-presentation within the OTTI-seminary "Cooling of office buildings" in November 2006. The manager of an enterprise (Klimashop, Augsburg), who sells and installs cooling and air conditioning devices for office buildings, showed interest in sustainable cooling strategies for his planned enterprise office building. Currently the discussions are going on.

Influence of KeepCool in this pilot project

The presentation of our project results in the Otti-seminary for planners, architects, building owners showed a good feed-back. Especially in the case of the new planned Klimashop building, we could influence the planning process as well as the cooling strategies. The project will probably be continued after the end of the KeepCool project.

4.3.3 Sweden: Västerport - a new office building in Stockholm

Building Owner

NCC Property Development

Type of building

This is a new office building, 30.000 m^2, under erection just outside the centre of Stockholm.

Actions taken

Climate simulations by the Swedish IDA-program showed that it is possible to establish an acceptable climate comfort in the summer without installing water based cooling (which is standard in office buildings in Sweden today). If the need for cooling is minimized the cooling needed can be provided with the air distribution system. The HVAC system uses only the supply air for ventilating, heating and cooling. Surplus heating and cooling (with water distributing systems) will not be needed. This means that simultaneously heating and cooling is avoided.

Cool outdoor air is used as long as the outdoor temperature is below indoor temperature, which is the case for most of the year in Sweden (except during daytime in extremely hot periods).

In this property the building and the HVAC system is designed to minimize the need for cooling by:

- The building will have heavy constructions to make it possible to store heat from daytime to night time.
- Limitation of window sizes
- Effective sunshades
- Recovery of cooling when outdoor temperature is above indoor temperature
- Night cooling
- Only when outdoor temperature is above +18 °C is district cooling used

Measures recommended

- No “over rating” of internal loads
- Energy efficient lighting, maximum 9 W/m2
- Heavy construction to enable storage of heat in concrete slabs and walls from day-time to night-time
- Limitation of window sizes
- High efficient sun shading
- Separate air handling units are to be placed on each floor in order to achieve individual cooling and heating for these floors with individual supply flows and supply temperatures. Hereby it is also possible to use only the units required for different time schemes and overtime work on different floors
- Cool outdoor air is used for cooling the building as long as the outdoor temperature is below indoor temperature. The heavy construction is cooled in the night time by outdoor air
- When the outdoor air is above 18 C the cooling of the ventilation air is complemented with district cooling

Short history

Two meetings with the HVAC consultants and the property developer have been held, and a regular correspondence has been exchanged regularly. We are now studying the plans from the HVAC consultants, NCC Engineering and Teknoplan. The integration of sustainable cooling measures is being discussed with NCC, namely reducing internal loads and correct input data in the simulation.

Influence of KeepCool in this pilot project

The normal method for heating and cooling in Sweden is by the use of water radiators for heating, fan coils or baffles for cooling and mechanical fans for ventilation. This leads often to ineffective temperature control. Our discussions in combination with the HVAC consultants ideas led to this different indoor climate solution in which ventilation, heating and cooling is achieved with only one system. On the other hand, in order to have a better regulation, the system has been decentralised with units in every floor. Important for the use of similar systems in the future is to evaluate the function of this relatively new and untested system. This result of this evaluation will hopefully help other property developer and HVAC consultants to use these systems in future.

4.3.4 Sweden: Ministry of Industry, Employment and Communications – refurbishment of office building in Stockholm

Building Owner

The National Property Board (SFV)owns most of Sweden's national building treasures. These include palaces and royal parks, theatres and museums, embassies, but also state administration buildings. In total SFV owns 1,800 properties in Sweden with a combined area of 1,6 million square metres. SFV manages 6,5 million hectares (around 16 million acres) of land - one seventh of Sweden's surface area. The duty of the Board is to administer them in the best possible way.

The task is not only to maintain the soul and character of each building but also to adapt them to present day needs and uses. SFV are also commissioned by the Swedish government to carry out new building projects which are representative for the nation.

SFV administers state-owned property and land at 73 locations in 69 countries around the world. In 44 of these countries SFV manages a Swedish Embassy. SFV is responsible for Sweden's 300 state-owned listed historical buildings together with organisations such as the National Heritage Board, the National Fortifications Administration and the Swedish Maritime Administration. SFV has approximately 320 employees across the whole of Sweden. and its work hails back to the 17th century.

Type of building

This example does not describe a specific building, but instead the strategy for indoor summer comfort applied within SFV.

Actions taken

A first meeting with Fastighetsverket showed that they have high ambitions regarding energy efficiency. Two common obstacles for the type of building SFV are: that the people working in the building do not have the same high ambitions (in the centre of Stockholm the buildings are occupied by ministries where people are extremely busy and not keen to discuss indoor climate and energy efficiency); and that in many buildings architectural concerns must be taken.

The Keep Cool recommendations have been compared with SFV's strategy and differences have been discussed.

Measures recommended

Below are the KeepCool recommendations with SFV-comments.

1. Define the thermal comfort objectives explicitly, using the Adaptive Comfort model where possible
   SFV – P25 or P27 (see above) is used. In some rooms even P23 (for ministers).

2. Intervene on the site layout and features of the surroundings which can affect summer comfort
   SFV – This is seldom done. Most of SFV's projects are existing buildings
3. Control and reduce heat gains at the external surface of the envelope
   SFV – Sun shades are used when possible.
4. Control and modulate heat transfer through the building envelope
   SFV – This is not applied. Only sun shades as above.
5. Reduce internal gains
   SFV – Energy efficient lighting is always installed. All internal loads that SFV can control are minimized.
6. Allow for local and individual adaptation
   SFV – Different comfort levels are applied in different rooms.
7. Use passive means to remove energy from the building
   SFV – Night cooling is used when temperatures allow.
8. Use active solar assisted cooling plants
   SFV – not applied. BUT SFV uses cool water from nearby sea water in Stockholm or district cooling.
9. If still necessary to reach the stated comfort objectives, use high efficiency active conventional cooling plants
   SFV – Cooling plants with the refrigerant R22 has been converted to R 507. R 507 is a refrigerant which consists of 50% HFC 125 (GWP 0,84) and 50% HFC 143a (GWP 1,0).
10. Train building managers and occupants on how to use, monitor performances and adequately operate and maintain the building.
    SFV – Applied.

Short history

The strategy above is continuously used in all projects when renovating or when tenants reorganise.

Fastighetsverket showed a special interest in learning more about the definition of summer comfort (indoor temperatures in the summertime) used in KeepCool and about of the definitions used in different countries. This information was provided.

SFV today uses an old Swedish recommendation called P25 (or P27). P25 means the indoor temperature can exceed 25C (27C for P27) not more than 10% of the working hours in a statistic month of July. SFV is now also looking at applying a new Swedish recommendation called "R1-guidelines for the specification of indoor climate" developed by the association of HVAC professionals.

Influence of KeepCool in this pilot project

Better understanding of comfort levels (indoor temperatures). SFV has shown a social interest in the reports on indoor temperatures from KeepCool (recommendations in different countries and the Swedish report). KeepCool has also made it possible for SFV to compare and update their strategy for cooling and to check state of the art for different technologies. SFV has shown a particular interest in the definition in summer comfort and indoor temperatures. The KeepCool definition can help SFV to be more flexible concerning indoor temperatures towards their tenants.

4.4 Discussion, conclusions

4.4.1 Success factors for a broad market influence

KeepCool examined and tested several marketing approaches, from direct advice to building owners in pilot projects, to education, press campaigns, events, and websites. The experience in eight countries show three success factors for the broad market implementation of sustainable summer comfort:

1. National awareness about energy efficiency in buildings,
2. Access to already existing networks of the target groups, and
3. A balanced and flexible marketing strategy.

In countries with an already high awareness of energy efficiency in buildings, KeepCool had easier access to the target groups: In Sweden for example, the city of Stockholm asked KeepCool for presentations and to meet municipal building managers and owners. Several Austrian newspapers asked for material, or published what they found on the project website. Renewed political interest into energy efficiency emerged in Italy. KeepCool presented its sustainable comfort steps to policy makers supporting their inclusion into the national energy efficiency policy. In Germany on the other hand, KeepCool first tried to organise a national conference on sustainable cooling and had to cancel it because of a lack of registrations, but became successful after having organised a well-represented architecture competition on sustainable cooling. Also in other countries, the project's results were basically creating or increasing awareness on sustainable summer comfort in order to create a first "foot in the door" within the target groups.

Another success factor was the existence, and the access to, already established dissemination networks. ecofacility in Austria started already in 2004, and KeepCool could join an already established network of building energy consultants. In Sweden, KeepCool could work with the networks of various professional associations. The higher effectivity and security of using existing dissemination channels was also the reason for presenting KeepCool at numerous international meetings instead of organising one stand-alone conference on sustainable summer comfort.

KeepCool had the biggest impact with a dissemination strategy where indirect marketing methods (press, information on the web, events etc.) and direct advice to the target groups supported each other. In countries, where one of these elements was not given, KeepCool had difficulties in reaching the desired impact: Pure information campaigns might have great influence, but it is impossible to monitor and allocate the results to the project. On the other hand, the offer of direct advice reached only a limited number of recipients without the support of a public information campaign or of a strong existing national network.

Another important point at the marketing strategy was its flexibility. An example can be given with the development of the KeepCool toolkit: Some partners based their marketing strategy on the toolkit, which was originally planned to be one of the first outputs of the project. However, for different reasons, the toolkit was only available much later than it had been planned. Partners who were waiting for the toolkit missed many opportunities for dissemination at the beginning of the project, while those who had a flexible marketing approach could make reasonable marketing and include the toolkit later.

4.4.2 Market barriers against sustainable summer comfort

Sustainable summer comfort has a long way to go in Europe. For its broad market implementation not only the addition of new technologies is required, but also a transformation of the present planning and tendering culture: From supplying and asking for “cooling” to supplying and asking for “comfort”. In the course of our project, we identified four main barriers against this transformation:

- Outdated rules of thumb in building envelope and cooling design;
- Remuneration schemes for planners and designers;
- Building codes concentrating on winter requirements;
- Scattered supplier industry for passive solutions.

In spite of better standards and design guidelines, often planners use outdated rules of thumb for design of the building envelope and the plants. In addition, the remuneration schemes for planners and designers do not support integrated planning; frequently the payment is mainly related to the size of the HVAC equipment built into a building, rather than to its performances. Furthermore, the building codes mostly concentrate on winter requirements, leaving summer energy efficiency for “green” architects and planners. And finally, as passive solutions are mostly a combination of different strategies, their supplier industry is scattered: suppliers are from different branches, and are less well organised than other industries in the construction sector.

4.4.3 What is the way forward for the dissemination of sustainable summer comfort?

Future actions are needed in order tackle the above mentioned four barriers. There is a great need for incentives for planners, architects and engineers towards integrated planning, for stronger summer requirements in national building codes, for wider diffusion of correct design rules for envelope and cooling systems and for a better cooperation between suppliers of components, systems, planners, architects and procurement specialists, along the entire market chain of sustainable summer comfort.

In addition, future actions should combine the three success factors that could be revealed within the course of the KeepCool project: Create national awareness, build upon existing professional network of the target groups or of powerful multipliers, and design a balanced and at the same time flexible marketing strategy.

The increasing pressure by high energy prices, by the risk of summertime blackouts and last but no least new developments in energy efficiency policy provide excellent stepping stones to further promote summertime energy efficiency: For the first time, the Directive on End-use Energy Efficiency and Energy Services (EEE-ESD) prescribes mandatory energy savings in all Member States, national Energy Efficiency Action Plans (EEAP) and an exemplary role of the public sector. Within this environment, an integrated service approach, seeking widespread support from existing associations and networks, will provide new levers of action, while at the same time helping to maximise the reach and impact of the KeepCool project’s findings.

5 Policy recommendations for sustainable summer comfort

5.1 Comfort legislation in the participating countries

5.1.1 Austria

Regulation on working conditions

The regulation of working places contains quite straight comfort prescriptions[8]. However, we have no knowledge about how strict these prescriptions are taken in the jurisdiction.

> "§ 28 (1) Care must be taken that the air temperature in working rooms remains between the following values:
>
> 1. Between 19 and 25 °C in rooms where work with little physical activities is performed;
> 2. Between 18 and 24 °C in rooms where work with normal physical activities is performed;
> 3. At least 12°C in rooms where work with high physical activities is performed.
>
> (2) In deviation to (1), care must be taken that in the warm season:
>
> 1. If air conditioning or mechanical ventilation is installed, air temperature possibly does not rise above 25 °C
> 2. otherwise other measures are taken to possibly lower the indoor temperatures.
>
> (3) It is possible to deviate from the above values, if these are not possible due to the usage of the room and:
>
> 1. these values are hold at least in the region of the workplaces, or, if this is not possible either,
> 2. other technical measures are taken to protect the occupants from unhealthy room climate. (i.e. radiative cooling etc.)
>
> (4) Is air conditioning in use, there must be
>
> 1. A relative humidity between 40 and 70 % (if there are no production technical reasons for deviation)
> 2. A thermometer and a hygrometer installed in the building."

This regulation indicates that in the regulation to the working conditions, the Fanger model is used with a portion of flexibility. The comfort temperature varies not with the outside temperature; there is different temperature levels for different activities; and, finally, there is a quite broad temperature range given together with a flexible formulation "care must be taken" or "possibly does not rise above…".

[8] § 28 Bundes-Arbeitsstättenverordnung (B-AStV, BGBL-II, pp. 2553-2577),

ÖNORM B 8110-3 Thermal protection in building construction[9]

This norm contains requirements for solar protection, thermal mass, and comfort levels. The norm itself is only a recommendation and is not legally binding; however, it will represent the „state of the art“ that is referred to in the new building code, in order to prove the “summer suitability” for new buildings. The norm provides threshold temperatures, and the determining factors for calculating the daily temperature curves in new buildings.

According to this norm, overheating in summertime is avoided (i.e. summer comfort is given),

1. if indoor temperature during using hours does not exceed:
   - +27 °C at daytime and
   - +25 °C at night, or
2. if solar protection, architecture, thermal mass and ventilation fulfil the following requirements:
   - The relations of air exchange and thermals mass to the immission-effective surface area are above given threshold values, and
   - Natural ventilation, operable windows or mechanical ventilation make daytime and night ventilation possible even if security issues are considered.

However, in order to avoid increased energy demand in the heating season, the norm also limits thermal mass to certain levels.

There are detailed guidelines how to calculate immission-effective surface and thermal mass. Internal heat sources must be considered, too. If they are not specified, the norm provides default values for calculation:

ÖNORM H 6020-1 Ventilation and Air-Conditioning in Hospitals[10]

This norm deals mostly with the special hygienic requirements of ventilation and air conditioning of hospitals. Beside these, it specifies temperature and humidity requirements for indoor spaces in hospitals. The norm follows a static model, i.e. sets temperature and humidity thresholds independent from the ambient temperature, with a relatively small tolerance level. Nevertheless, it specifies different temperature targets for different types of rooms. These vary from 22-24 °C in operating rooms to 26 °C in most rooms and 28 °C in electric control rooms. Mechanical ventilation and air conditioning is only required for room types with high hygienic demands such as operating rooms, intensive care units, sterile rooms etc. In all other rooms, including normal patient stations, mechanical ventilation is required only if natural ventilation is not sufficient to keep the rooms within the thermal and humidity thresholds. Rooms without medicinal work such as offices, machine rooms, auditoria etc. are not subject to these regulations.

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[9] ÖNORM B8110-3 Wärmeschutz im Hochbau: Wärmespeicherung und Sonneneinflüsse (Thermal protection in building construction - Heat storage and solar impact) www.on-norm.at

[10] ÖNORM H 6020-1 Ventilation and air conditioning plants in hospitals: Design, construction and inspection (www.on-norm.at)

ÖISS-Guideline for ecologic criteria in school buildings[11]

These guidelines will be obligatory in Vienna, and will be stepwise included into the obligatory federal guidelines of the ÖISS. They encompass new construction and comprehensive refurbishment of school buildings. One chapter is dedicated to summer comfort.

At hot summer days, indoor temperature shall stay at least 3 °C, but not more than 6 °C below the maximal outdoor temperature.

The use of active cooling must be avoided. If necessary, cooling need must be met with passive systems such as storage mass, appropriate shading and night ventilation. The ability of the building to provide appropriate summer comfort must be given with the calculation method of ÖNORM B 8110-3 or with an acknowledged building simulation programme (e.g. TRNSYS).

Further, the guidelines provide examples for influencing factors and for good practice for summer comfort. The influencing factors for summer overheating are:

- Scale and orientation of glass surfaces
- Efficacy of solar protection
- Natural ventilation of the inner space
- Thermal mass
- Internal heat sources: Occupants and devices (IT)

Good practice recommendations are:

- Possibility for night ventilation
- Cross-ventilation
- Thermal mass in floor & ceiling, if possible in the walls and on-floor objects, too.
- Avoiding high heat effects of artificial light, IT or electric devices.

The chapter on lighting details the priority and planning requirements of daylight, light requirements, appropriate light control systems and energy efficient artificial lighting. Guiding values for artificial lighting are 15 W/m2 for 500 lx, and 9 W/m2 for 300 lx.

Mechanical ventilation systems are only recommended if “committed personal operation and maintenance” is available. Single ventilation appliances shall not require more than 0,4 W/m3, and central ventilation systems not more than 0,6 W/m3.

Mechanical cooling is to be avoided. Comfortable temperatures must be reached by architectural measures, outside shading, and energy efficient electric equipment.

Beside the actual need the energy efficiency must have highest priority when equipping a school with electric devices and IT. This not only in order to keep electricity and running costs low, but also in order to avoid unnecessary indoor heat development. Server rooms must be located close to the façade in order make natural ventilation possible. The utilisation of the inevitably produced heat (via controlled ventilation and heat exchangers) must be checked.

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[11] Draft guideline of the ÖISS, Austrian Institute for School and Sport Buildings Construction. Drafting in progress.

5.1.2 Germany

Thermal comfort within EnEV2004 and DIN 4108-2

Three typical climate regions are defined, with the following characteristics as well as limits (e.g. for maximum internal temperatures):

Summer-region	Characteristic	Monthly average outdoor temperature	Maximum indoor temperature
A	Cool summer	Below 16,5 °C	25 °C
B	Moderate summer	Between 16,5 and 18 °C	26 °C
C	Hot summer	Above 18 °C	27 °C

Table 9: Maximal indoor temperatures for three climatic regions in EnEV 2004 and DIN 4108-2

Satisfying summer heat protection method according to EnEV 2004 and DIN 4108-2 means, that in less than 10% of the average occupation time (10 h/d for office buildings) the limit for the internal temperature is exceeded.

Thermal comfort within DIN1946, part2

Another model is used in DIN 1946, part 2, which has to be considered in principle when mechanical ventilation systems are installed in a building. For the planning and dimensioning of ventilation systems DIN 1946, part 2 describes the possibility to realise either a constant operative room temperature (composed of room air temperature and radiation) or even a shift of the room temperature depending on the outdoor air temperature. In this case a maximum operative room-temperature of 25°C is recommended for outdoor air temperatures up to 26°C – short term exceeding is allowed. For higher outdoor temperatures than 26°C a rise of the operative room temperature of 0,33°C per Kelvin temperature rise of the outdoor temperature is admissible. Figure 17 illustrates this shifting operation mode.

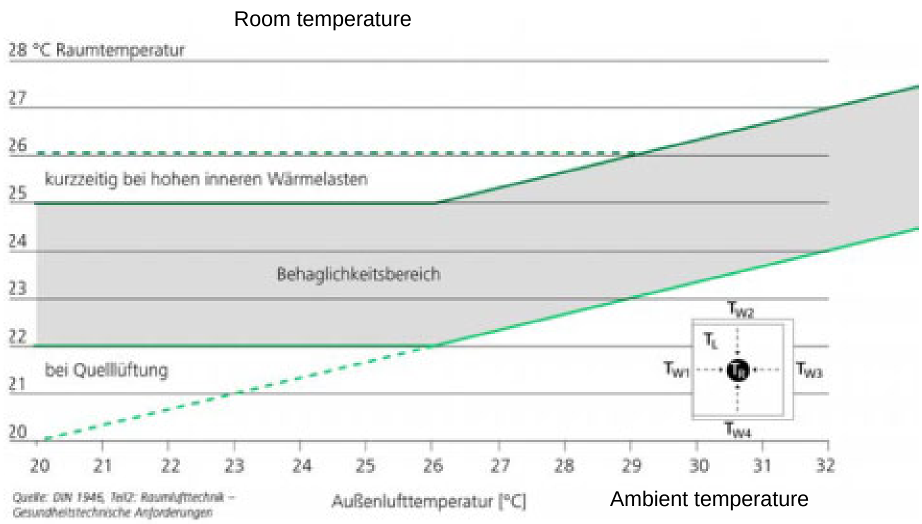

Figure 17: Thermal comfort area in DIN 1946, part 2

Further, this standard gives a comfort range for the humidity-content of the air. The upper limit should be 65% relative humidity, with a maximum of 11g water per kg dry air. The lower values should not fall below 30% relative humidity, where occasional shortfalls are admissible. In practice the thermal comfort criteria of DIN1946, part 2 are often applied for all kinds of buildings (even without mechanical ventilation systems).

The new "Energieeinsparverordnung 2006 / DIN V 18599" will provide a standardised calculation methodology to evaluate the climatisation needs of a building, but the reference values are not clear at this point of time. Other future legislation will give overall primary energy figures for the whole building (heating, warm water, climatisation, lighting, ventilation), which could help sustainable cooling to be one possibility for optimisation. A weak point in the future legal framework is that no limit or target values for individual crafts are given.

5.1.3 Italy

In Italian norms the summer comfort is not explicitly defined. There are just some technical norms which suggest how to calculate the summer operative temperature inside not cooled rooms and the set-point temperature for the dimensioning of plants. The UNI EN ISO 7726-2001 ("Ergonomics of the thermal environment - Instruments for measuring physical quantities") standard refers to ISO 7730 and the Fanger comfort model.

There are some local codes that propose adaptive suggestions but not a complete adaptive approach. For example, a regional circular of Veneto (n. 38-87) about security in new tertiary buildings recommend that the temperature difference between inside and outside do not exceed 7°C.

5.1.4 Lithuania

Lithuanian Hygiene Norm HN 69:2003

The Lithuanian Hygiene Norm HN 69:2003 "Thermal comfort and sufficient thermal environment in the working premises" lays down thermal comfort, humidity, or air quality level for cold and warm year seasons.

Lithuanian Hygiene Norm HN 42:2004

The Lithuanian Hygiene Norm HN 42:2004, Microclimate in dwelling and public buildings, was approved by the Minister of Health of the Republic of Lithuania. This Hygiene Norm lays down the parameters for sufficient thermal environment and thermal comfort as well as their values in the premises of residential and public buildings, whereby it refers to the international standard ISO 7730.

In this hygiene norm the acceptable parameter values of thermal environmental and the thermal comfort parameters are normalized separately for cold and warm year seasons. The following parameters are laid down:

- Air temperature
- Appreciable temperature
- Temperature difference between 1.1 and 0.1m from the floor surface
- Temperature difference between buildings envelops and room temperatures
- Relative air humidity
- Movement velocity

The thermal comfort parameters in summer season are explicitly stated:

- There is a fixed temperature set point band 23-25 degrees Celsius, for the thermal comfort.
- There is a fixed temperature set point band 22-28 degrees Celsius, for the acceptable parameter values of thermal environmental.

There are no limitations for applications for sustainable comfort. However, thermal comfort conditions in Lithuania are achieved mainly through active measures and energy demands for this are not limited either.

5.1.5 Portugal

The Portuguese codes for building envelope and HVAC[12] systems have been recently updated in order to comply with the EPBD.

The new building envelope code (Decree-Law n. 80/2006, RCCTE) imposes requirements for building envelopes, both for the winter and the summer season, and for water heating production. The code divided geographically the country in three winter zones and three different summer zones, according to the prevailing climatic conditions. In the more severe climatic zones, the level of requirements is correspondingly tougher. These regulations apply to new residential and tertiary buildings, without centralised HVAC systems. Buildings undergoing large rehabilitation process are also included.

The RCCTE code establishes limits for the maximum allowable useful energy needed for (i) space heating - article 5 (ii) cooling - article 6 and (iii) water heating - article 7, in terms of kWh/(m²a). The code also limits the primary energy needs (only referring to the 3 above mentioned energy uses). The maximum values are defined in article 15. The limit for space heating energy need is defined by using a parametric expression that takes into account the surface to volume ratio and the number of annual degree-days. The maximum value for cooling depends only on the climatic zone where the building is located (for Lisbon area the limit is 32 kWh/m²/year). Regarding water heating, the limit is only dependent on the volume of water use throughout the year. The code imposes the use of solar water heating systems, if the direct solar radiation is available.

The new HVAC code (Decree-Law n. 81/2006, RSECE) establishes maximum limits for the annual energy consumption of large existing non-residential buildings (article 7). This limit is

[12] HVAC – Heating, Ventilation and Air Conditioning

defined by fixed values (specific energy indicators) dependent on the type of the building. These buildings shall have periodic energy audits. If the real energy consumption is greater than the limit value then an energy efficiency plan must be implemented.

RSECE also imposes limits to the maximum level of energy consumption for large new (or large rehabilitation) non-residential buildings (article 8). A detailed building energy simulation should be carried out in order to estimate the energy consumption of the new building. Limits are also defined by fixed values for each type of building. New small tertiary buildings with HVAC systems have limits for overall energy use (simplified simulation results below fixed limit values) and their space heating and cooling energy needs shall be 20% below the limits defined by RCCTE code. Finally, the energy needs for heating and space cooling of new residential buildings with centralise HVAC systems should be below 20% of RCCTE limits.

RSECE imposes a set of prescriptive conditions on HVAC systems: maximum thermal power allowed, minimum efficiency of boilers and the minimum COP of chillers, the use of heat recovery of exhaust (rejected) air, the use of free-cooling in large duct air installations, the use of control systems with limitation on temperature levels in order to avoid overheating in winter and overcooling in summer, the use of energy meters, the use of centralised energy management systems in large installations, etc.

RCCTE is an integrated performance based code, which gives some degree of freedom to the designer. However, additionally, there are prescriptive conditions based on two critical parameters: the heat loss coefficient (U) for each building component and the solar factor of each glazed area. These parameters have maximum values (Annex IX) that cannot be exceed for each building component. Air renovation, thermal inertia, façade colour and thermal bridges are other parameters that have to be defined for the specific case in order to calculate the useful energy needs.

The maximum values for solar factor of glazing (summer requirements) depend on the level of thermal inertia (light, medium or heavy) and the summer climatic region where the given building is located.

Summer comfort is considered in both RCCTE and RSECE mentioned above. Each regulations have separated sections to deal with winter and with summer. The purpose of both regulations, concerning the summer season, are establishing the conditions necessary to provide summer comfort without an “excessive” use of energy.

In the new revised versions, summer comfort appears explicitly. The physical formulation of both RCCTE and RSECE is based on a summer comfort temperature of 25 °C and 50% of relative humidity. These values can be modified by a lower level law (“Portaria”).

In existing buildings, it is difficult to characterise the prevailing indoor thermal comfort conditions due to the absence of data and reports. However, the general view is that large buildings, mostly with HVAC systems, tend to operate with set-point band (Fanger model). Other buildings, some with HVAC systems and many not (despite the fast market penetration rate), operate with set-point band when the cooling loads are high and probably operate based on occupant behaviour when cooling loads are low (the occupant may turn off the cooling system if he/she is comfortable with open windows and light clothes).

Some sectors (hotels, shopping malls, banks, etc.) may have they own practice motivated by what they consider “quality of service”. In this case, they may have stricter set-point band and make some inspections to verify the levels of compliance.

Concerning the planning or design phase, the current practice is to use the Fanger model because engineering courses teach in this way. However, in some cases, designers use “non-justified” comfort parameters (e.g. comfort summer temperatures between 22-24 °C). Also, some sectors may have their specific guidelines, which may be more or less flexible. Four and five star hotels are a very well known case of prevalence of thermal comfort guidelines which are very stricter.

5.1.6 Scotland

The Scottish Building Standards state that “particular attention should be paid to limiting overheating, by ensuring that areas of the external building fabric which are susceptible to solar gain have appropriate areas of translucent glazing and/or solar shading. A ventilation strategy that incorporates night cooling and the thermal mass of a building can also be used for effective control”. Hereby, no direct reference is made to summer comfort. The Carbon Performance index is considered in connection with the building regulations. Overall energy consumption is considered by reference to Good Practice guidance.

The Workplace (Health, Safety and Welfare) Regulations 1992 - “During working hours, the temperature in all workplaces inside buildings shall be reasonable”. However, the term “reasonable” with regard to temperature is not defined. Building Regulations refer to the Technical Handbook which says how things “should” be done. The Technical Handbook in turn refers to other technical guidance, e.g. CIBSE Guide. CIBSE AM10 “Natural Ventilation in Non-Domestic Buildings” refers to ISO 7730 and also the additional factors of the “Adaptive Principle”.

The guidance implies that an adaptive approach should be used in naturally ventilated buildings.

CIBSE Guide A(6), Table 1.1, gives recommended summer and winter dry resultant temperatures corresponding to a mean predicted vote of ±0.25 for a range of building types. However, as noted in Guide A, control within an air conditioned building is normally based on a response to internal air temperatures. In a standard office environment this corresponds to 22-24 °C and 21-23 °C where comfort cooling or air conditioning, respectively, are available. In a naturally ventilated environment, the acceptable dry resultant temperature range is less well defined and various approaches have been suggested.

5.1.7 Spain

The Technical Building Code is the energy regulation applicable for buildings in Spain. This regulation addresses some issues (articles: 4, 5, 6, 9, 10) of the EPBD (European Communities, 2003). The remarks below have been considered for this new regulation. There is a mandatory request for energy demand of the entire building, not for the energy consumption; there is one different level for winter or for summer. These levels depend on several issues:

- Location of the building
- Occupancy and functional parameters
- Geometry of the building

For instance, taking two locations in Andalusia with different weather requirements, Cádiz and Sevilla, mandatory levels obtained for an average office building are:

	Cádiz	Sevilla
Heating Demand (kWh/m²a)	6	15
Cooling Demand (kWh/m²a)	15	25

Table 10: Mandatory levels for energy demand of buildings in two different Spanish regions

Alternatively, there are requirements for the energy performance of components (Table 11). This also depends on the location of the building, orientation of façades, and other parameters, like glazing percentage per façade or internal loads.

	Cádiz	Sevilla
Transmittance of walls W/m²K	0,94	0,82
Transmittance of roofs W/m²K	0,50	0,45
Transmittance of floors W/m²K	0,53	0,52
Transmittance of windows W/m²K (*)	5,7	4,8
Solar factor of glazing (**)	0,56	0,48
Solar shading	Not considered	

Table 11: Requirements on the energy performance of building components in two different Spanish regions.

(*) East West façade with 30% glazing percentage

(**) East West façade with 30% glazing percentage and 6 kWh/m²a internal load

Thermal comfort is explicitly defined in the Norm ITE 02 from the Law RITE inside the Technical Building Code. It is defined on the Spanish Building Code according the international standards: ISO 7730, ISO 8990, ISO 9920, ISO 7726, EN 13779, EN 13053.

The theory used as a basis for calculating thermal comfort and indoor air quality, can be found in the following regulations: ASHRAE 55-1992, ASHRAE Standard 62-1989R, ENV 1752, ISO 8996, ISO 7243, ISO 7933, ASHRAE 113-1990; and in the following ASHRAE Handbooks: 1987 - HVAC Systems and Applications, 1995 - HVAC Applications, 1996 - HVAC Systems and Equipment, 1997 - Fundamentals.

In the legislation, the Fanger Model is used. Fixed Temperature set point bands for winter and summer are given with 20ºC – 24ºC for winter and 23ºC – 26ºC for summer.

In the regulation about working conditions (RD 486/1997), summer comfort is established as the range of temperatures: [17ºC, 27ºC], and [30%, 70%] for relative humidity.

According to the Norm ITE 02.2.2 from the Law RITE, mechanical ventilation is mandatory in all tertiary buildings.

5.1.8 Sweden

Regarding summer thermal comfort the Swedish Work Environment Authority compiled an official communication ("How hot can it be indoor" PM-CTB 23114, Swedish Work Environment Authority). It is mentioned that:

- there are no maximum temperature in the regulations since thermal comfort depends on several factors, but it is acceptable to take the air temperature as the indicator for thermal comfort;
- Comfort temperatures for a light activity are normally between 22 (normal clothing) and 24 °C (light summer clothing). If the temperature exceeds 26 °C for a long period (how long is not defined) then it should be investigated.
- a temperature up to 30 °C implies only a moderate stress, if it is only under a "warm bubble" and does not require normally permanent measures. However temporary measures can be needed. Measures are normally needed when the temperature exceeds 30 °C. The investigation should follow the methods according to SS-EN ISO 7730. The results of the investigation need to be analysed taking into account the type of activity namely with a working environment engineer from the companies healthcare centre. In this type of working environment questions should the working environment's ombudsman also be involved.
- Section 45 of the regulation § AFS 2000:42 requires that shutters, blinds or other shading devices are used whenever needed.
- Section 39 § in AFS 2000:42 requires that water should be made available in hygienic and practical way.

For the residential sector the act SFS 1998:808 of the Environment Code says that a temperature greater than 28 °C causes a nuisance to human health. This is used by the Swedish Work Environment Authority as a reference for comparing thermal comfort conditions.

There is a limit, expressed in kWh/m² to the sum of thermal energy losses + electricity consumption among others in cooling systems. So any consumption related to cooling will imply minimized thermal losses in the heating season as there is a limit to the global energy consumption. It is also mentioned that the buildings should be designed, and that technical measures should be taken into account, in order to minimize cooling need (chapters 6.1 and 9.51). Under "general recommendations" several alternatives are mentioned: the use of shading devices, adequate sizing and orientation of windows, efficient lighting and equipment, free cooling, cooling storage using the buildings shell's inertia, etc. It is also mentioned that efficient cooling systems should be used (9.1.)

There is a large program providing subsidies to energy efficiency investments in public service buildings (education, sports, offices, health, etc). The subsidy in the form of a tax credit can be up to 30 % (PV 70%), limited to 900 Euro per building. The total amount is 180 million Euro. Concerning cooling, connections to district cooling and other cooling systems are funded. It requires an energy audit, implementing subsequent measures to reduce cooling loads such as efficient lighting, use of solar protection devices, free cooling, among others. There are also terms of references or program requirements developed by the Swedish Energy Agency that function as guidelines for developers on a voluntary basis. A number of large building owners/operators have internal requirements regarding cooling.

5.2 Allowing for thermal comfort in free-running buildings in the new European Standard EN15251

5.2.1 Acknowledgments

The text in this section was taken from (Nicol & Pagliano, 2006). We would like to express our gratitude to Prof J. Fergus Nicol from the London Metropolitan University for his permission to use his contribution in this report. Evidence supporting the use of the Adaptive Comfort Model, simulations on its application and considerations on categories have been developed, summarised in the appropriate language and formally brought to the attention of the drafting group of prEN 15251 by Prof. Nicol and Dr. Lorenzo Pagliano from the KeepCool project team. This was done by means of ECOS, European Environmental Citizens' Organisation for Standardisation, which has Associate status with CEN. Some National Standardisation Bodies supported the presentation of parts of the amendments proposed. We would also like to acknowledge the role of Rev Prof Michael Humphreys in developing many of the ideas presented.

5.2.2 The adaptive approach to thermal comfort

The Adaptive Approach to thermal comfort (Humphreys and Nicol, 1998) has been developed from field-studies of people in daily life. While lacking the rigour of laboratory experiments, field studies have a more immediate relevance to ordinary living conditions (deDear 1998; Humphreys, 1975; Auliciems, 1981). The adaptive method is a behavioural approach, and rests on the observation that people in daily life are not passive in relation to their environment, but tend to make themselves comfortable, by making adjustments (adaptations) to their clothing, activity and posture, as well as to their thermal environment. The results and analysis of the interviews to people in real buildings, free floating, are presented in the SCAT database and the ASHRAE RP884 database.

Over time people tend to become well-adapted to thermal environments they are used to, and to find them comfortable. Adaptation is assisted by the provision of control over the thermal environment to give people the opportunity to adapt. This ‘adaptive opportunity’ (Baker and Standeven 1996) may be provided, for instance, by fans or openable windows in summertime or by temperature controls in winter. Dress codes will also have consequences for thermal design, for services provision, and consequently for energy consumption. A control band of ±2 K should be sufficient to accommodate the great majority of people (Nicol and Humphreys 2007).

These customary temperatures (the ‘comfort temperatures’) are not fixed, but are subject to gradual drift in response to changes in both outdoor and indoor temperature, and are modified by climate and social custom. Field research can indicate the extent and rapidity of adaptation, and hence of the temperature drifts that are acceptable. During any working day it is desirable that the temperature during occupied hours in any day should vary little from the customary temperature. Temperature drifts much more than ±2 K in any day would be likely to attract attention and might cause discomfort.

Clothing and other adjustments in response to day-on-day changes in temperature, will occur when a building is responding to weather and seasonal changes. These will occur quite gradually (Humphreys 1979; Nicol and Raja 1996; Morgan, deDear & Brager, 2002), and can take a week or so to complete. So it is desirable that the day-to-day change in mean indoor operative temperature during occupied hours should not occur too quickly for the adaptive processes to keep pace.

During the summer months many buildings in Europe are free-running (i.e. not heated or cooled). The temperatures in such buildings will change according to the weather outdoors, as will the clothing of the occupants. Even in air-conditioned buildings the clothing has been found to change according to the weather (deDear and Brager 2002). As a result the temperature people find comfortable indoors also changes with the weather (Humphreys 1981). Thus the temperature people find comfortable can vary quite considerably depending on the climate, but any change should occur sufficiently slowly to give building occupants time to adapt.

5.2.3 Comfort in buildings

In buildings which are in free-running (FR) mode indoor conditions will follow those outdoors but will be modified to a greater or lesser extent by the physical characteristics of the building and the use which building occupants make of the controls (windows, shading devices, fans etc) which are available to them. In a successful building these actions, together with the changes which the occupants make to their own requirements – mainly through clothing changes – mean that occupants are able to remain comfortable most of the time. The function of a standard is to define the indoor conditions which occupants will find acceptable for any given outdoor condition.

Humphreys (1979) showed that the temperature which occupants of FR buildings find comfortable is linearly related to the monthly mean of the outdoor temperature. Other researchers have since found similar results (e.g. deDear and Brager 2002). The SCATS survey based in 5 European Countries has increased the accuracy and applicability of the model by showing that it is the running mean of the daily mean outdoor temperatures which correlates best with indoor comfort temperature (McCartney and Nicol, 2002) and that for free-running European offices the linear relationship is:

$$Tc = 0.33Trm + 18.8 \qquad (1)$$

where Tc is the optimal operative temperature for comfort and Trm is the running mean of the daily mean outdoor temperature. Full definitions of the running mean temperature are given in McCartney and Nicol (2002) and in chapter 1 (section 1.6) of the CIBSE Guide A (2006), and a way is given to calculate it iteratively from its value of the previous day and the measured current day temperatures. It should be mentioned that this relationship strictly applies to the subjects who took part in the SCATs surveys and the buildings they occupied, but it closely matches the relationship presented by deDear and Brager from their survey of buildings throughout the world (ASHRAE database rp884) and this suggests that it has general applicability.

In Figure 18 and Figure 19 below we present for two climates and typical years the evolution of external air temperature and the indoor operative comfort temperatures.

Adaptive Operative Comfort Temperature is calculated according to Equation 1; Fanger Operative Comfort Temperature is calculated using the formulas presented in ISO 7730 and assuming the following values of the input variables:

- thermal resistance of the clothing (Clo) = 0.5 clo
- metabolic rate (Met) = 1.4 met
- air velocity (V) = 0.15 m/s
- relative humidity (Ur) = 50%

This corresponds to general practice when using the Fanger model, where building planners have to make an assumption on those values adopting an average reasonable value for the entire season, and hence obtaining a constant value for the Comfort Temperature.

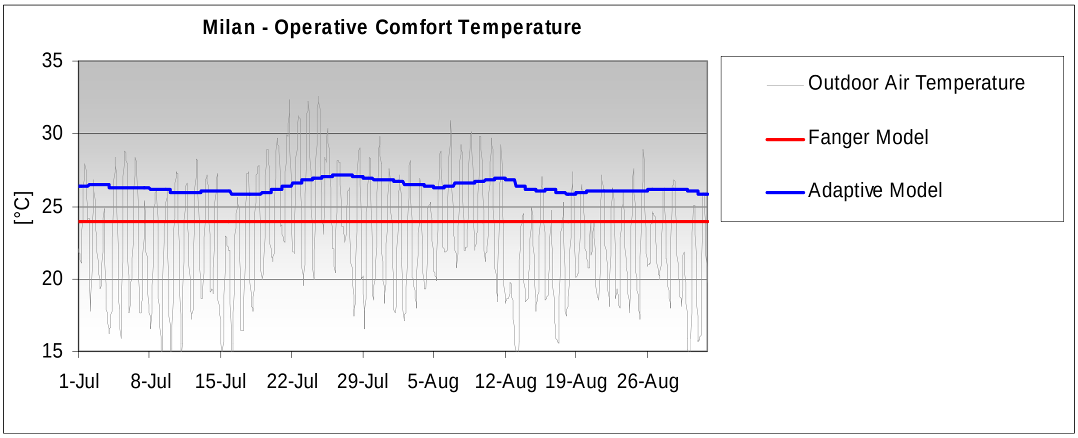

Figure 18: Adaptive Operative Comfort Temperature and Fanger Operative Comfort Temperature for standard summer outdoor temperatures in Milan, Italy

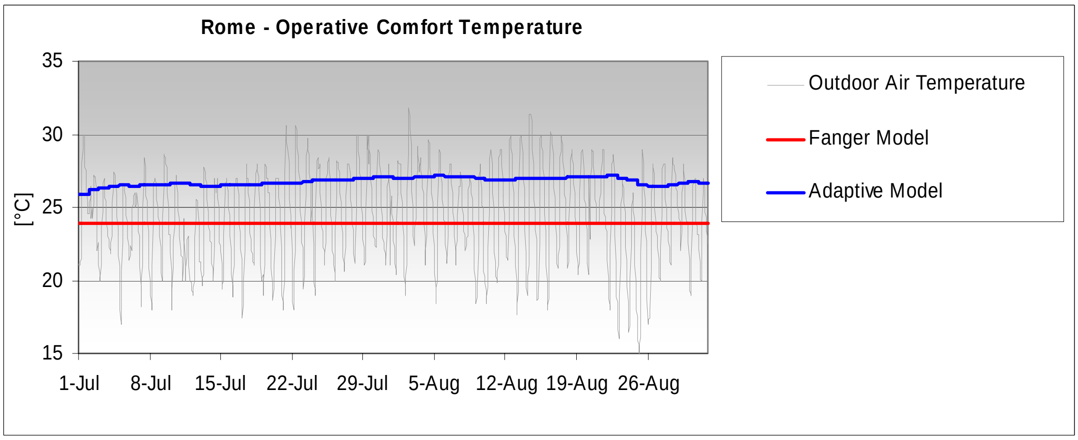

Figure 19: Adaptive Operative Comfort Temperature and Fanger Operative Comfort Temperature for standard summer outdoor temperatures in Rome, Italy

Having defined an optimal comfort temperature Tc, based on the interviews, the question arises of how far the temperature of a space can deviate from Tc before discomfort will occur. Nicol and Humphreys (2007) have analysed the data from SCATs and showed that 'the temperatures at which discomfort will not be unduly intrusive are up to ±2 K above or below the appropriate comfort temperature', which makes this a sensible limit for a comfort zone.

5.2.4 EN 15251 and temperature limits in free running buildings

The preamble of the European Energy Performance of Buildings Directive (EPBD) states: "(...) the displaying of officially recommended indoor temperatures, together with the actual measured temperature, should discourage the misuse of heating, air-conditioning and ventilation systems. This should contribute to avoiding unnecessary use of energy and to safeguarding comfortable indoor climatic conditions (thermal comfort) in relation to the outside temperature." (European Communities, 2003, p. L1/66). Ensuring that both energy savings and a good indoor environment are targeted is essential (Varga and Pagliano 2006). The European Standard EN 15251 "Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics" seeks to define minimum standards for the internal environment in buildings to complement the EPBD. A major consideration of the EN is to ensure a correct definition of thermal comfort.

The International Standard EN ISO 7730-2005 makes no allowance for differences in comfort conditions in naturally ventilated (NV) and mechanically cooled (AC) buildings. For this reason it is important that EN 15251 embodies the latest thinking about comfort in the variable conditions of real NV buildings, allowing designers to take advantage of occupants' natural ability to adapt conditions to their liking. This not only optimises the interaction between occupants and the building to ensure comfort but also enables designers to maximise energy saving by allowing indoor conditions to track those out of doors. EN 15251 makes a distinction between buildings which are heated and/or cooled (HC) and those which are free running (FR). Thus NV buildings will be HC during the heating season and FR during the summer; AC buildings are HC through-out the year. In Standard EN 15251, the comfort zone for HC buildings is defined as in EN ISO 7730 (2006).

Category	Explanation	Suggested acceptable range
I	High level of expectation only used for spaces occupied by very sensitive and fragile persons	± 2K
II	Normal expectation (for new buildings and renovations)	± 3K
III	A moderate expectation (used for existing buildings)	± 4K
IV	Values outside the criteria for the above categories (only acceptable for a limited periods)	

Table 12: Suggested applicability of the categories and their associated acceptable temperature ranges.

EN 15251 uses the results of the SCATs survey to define the limits of temperatures in buildings divided into categories defined as shown in Table 12. The width of the acceptable zones allowed in each category is shown as a deviation from the value which is calculated from Equation 1. The applicability of the zones is assumed to be for values of Trm between 10°C and 30°C. EN 15251 has also introduced an allowance for air movement which can mean that the upper limit of acceptable temperature can be raised when substantial air movement is present such as might occur when a fan is in use. Figure 20 shows the design values for the four categories in NV buildings. For more details, especially for noise levels, air quality and the temperature limits for AC buildings, see Olesen (2007).

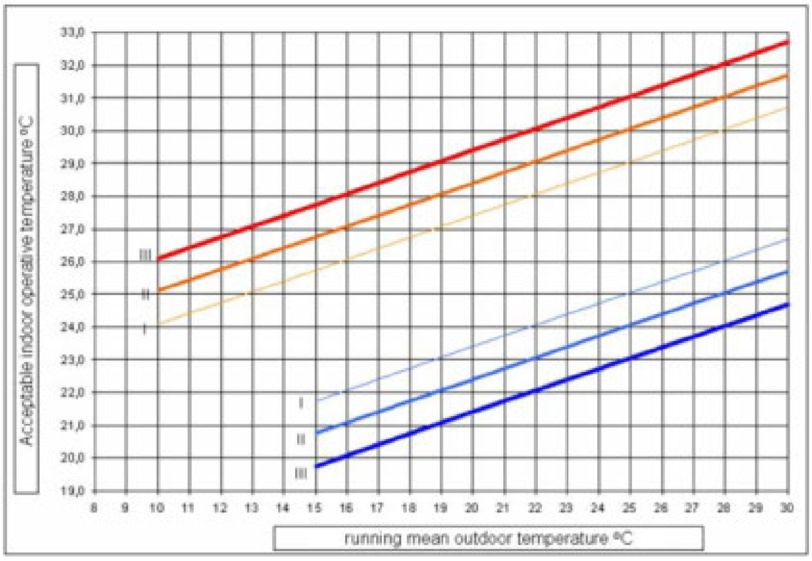

Figure 20: Design values for the indoor operative temperature for buildings without mechanical cooling systems as a function of the running mean of the outdoor temperature (McCartney and Nicol, 2002, cited in Olesen, 2007).

5.2.5 Evaluation of thermal conditions for compliance with EN 15251

There are two methods suggested in the EN for evaluating the thermal comfort conditions:

1. Percentage outside range: the proportion of the occupied hours during which the temperature lies outside the acceptable zone.

2. Degree hours criterion: The time during which the actual operative temperature exceeds the specified range during occupied hours is weighted by a factor depending on the number of degrees by which the range has been exceeded

Acceptability of the space on the ‘percentage’ criterion is on the basis that the temperature in the rooms representing 95% of the occupied space is not more than 3% (or 5% - to be decided) of the occupied hours a day, week, month or year, outside the limits of the specified category. Acceptability for the degree hours criterion are still to be decided. Subjective evaluation may also be accepted in existing buildings and methods for evaluating this are given.

5.2.6 Conclusions

The proposed new European Standard prEN 15251 has been framed to allow the natural variability of the indoor climate in free running buildings to be matched to the natural ability of people in well designed buildings with adequate occupant control, to change their room conditions to suit their needs. This will mean that buildings can be designed which are both comfortable and can make full use of passive, low energy cooling and heating technologies.

5.3 Introducing summertime energy efficiency into national energy policies

Partly as a result of the efforts to transpose the EPBD into national legislation, 18 Member States (MS) have adopted or are prepared to adopt requirements regarding summer comfort in the building regulation for new buildings (Gonçalves, 2006). This shows an increasing attention given to summertime energy consumption. However, these summer requirements only apply to new buildings and major renovation, so that the great majority of the building environment will not be affected. Therefore, specific marketing activities are needed if the summer requirements are to give results – especially targeting the existing building stock.

In Austria, KeepCool succeeded to introduce limits to cooling energy demand for new construction and major refurbishment of non-residential buildings into the new building code, and made recommendations to include summertime energy efficiency measures into the environmental subsidy scheme. In Italy, KeepCool was involved into the development of both building regulations and the regulations regarding incentives to energy efficiency projects. In Andalusia, the regional energy agency who is regulating the subsidy scheme was directly participating in KeepCool and included sustainable cooling technologies into the measures funded. In Sweden, Lithuania and Germany, KeepCool achieved to inform relevant actors, but further work will be needed to incorporate sustainable summer comfort into the regulations.

5.3.1 Influence to Austrian building code and subsidy schemes

Building Code

In Austria, building regulations are in the competence of the regions. With the national implementation of the EPBD, nine different building codes had to be harmonised. This harmonisation has been made via the guidelines of the Austrian Institute of Building Technology, the OIB-Guidelines, which will be ratified by each region separately.

The Austrian Energy Agency has been involved in the harmonisation process and the development of the new OIB Guidelines from the beginning in 2004. AEA staff developed the complete calculation methods, made recommendations for minimum requirements of energy efficiency in terms of maximal thresholds in heating and cooling demand, and attended numerous workshops with federal and regional decision makers facilitating the finalisation of the guideline. The knowledge gained from the KeepCool project was very helpful when proposing and defending limitations in cooling demand.

In April 2007, the new OIB guidelines passed the final vote through the regional delegates. Guideline No. 6 “energy efficiency and thermal insulation” sets minimum requirements for the energy efficiency of buildings. These are defined in three steps:

- U-values of buildings components (all buildings);
- Net useful energy demand (heating demand for residential buildings, heating and cooling demand for non-residential buildings);
- Final energy demand for residential buildings,

Newly constructed non-residential buildings will either have to comply with “ÖNORM B-8110-3 Thermal protection in building construction - Heat storage and solar impact” which is introduced in section 5.1.1 above, or they prove that the externally induced cooling demand is limited to 1 kWh/m³a which corresponds to 3-4 kWh/m²a. For existing non-residential undergoing major refurbishment the same requirements are valid, with a higher threshold value of 2 kWh/m³a which corresponds to 6-8 kWh/m²a. The externally induced cooling demand represents the solar heat gains, without taking into account internal heat loads or the ventilation strategy, and is therefore a good criterion for the overall quality of the building envelope and structure.

The same guideline contains the regulations concerning the energy certificates following the EPBD. Here, in spite of all of our efforts, we did not succeed to integrate cooling energy demand into the determination of the energy efficiency classes. Due to a political decision, the energy efficiency classes will be determined by the heating demand of buildings alone. Cooling demand is displayed separately on the back of the certificate. This leads to the precarious situation that while cooling demand of new constructions is limited, existing buildings with a high cooling demand will get erroneously good certificates.

Subsidy Scheme

In the frame of the Austrian environmental subsidy programme (so-called Umweltförderung) there is a scheme targeting at the thermal modernisation of non-residential buildings. For the moment, this scheme subsidises the thermal refurbishment of hotels, administration buildings, schools etc. exclusively related to a reduction of the net heat demand of the building – i.e. it targets only at the refurbishment of the building envelope for the winter season. It does not address the following issues:

- reduction of net energy demand for cooling;
- improvement of the technical systems inside the building;
- optimisation of new construction.

In several meetings with the ministry environment, who is responsible for the environmental subsidy programme, and with Kommunalkredit, who is administering the programme, the following topics related to a further development of the scheme on the thermal refurbishment of non-residential buildings have been discussed:

- The observable increase of electricity consumption for cooling demonstrates the need to include the (reduction of the) cooling demand in the subsidy scheme;

- The revised subsidy scheme should be based mainly on the part of the net cooling demand that is related to solar gains, since this value represents a simple but also reliable benchmark of sustainable summer comfort in the building. The amount of subsidies should be directly dependent on this value;
- In addition to the value of (solar-based) net cooling demand there should be an extra subsidy for innovative cooling technologies, such as night ventilation systems, earth to air underground heat exchanger, energy sonds, solar active cooling etc.
- The subsidy scheme should be enlarged also to newly constructed buildings.
- The calculation procedures for net cooling demand and cooling energy consumption should be the same as foreseen for the new building code according to the EPBD.

In 2006 the ministry of environment prepared a new legal act on environmental support schemes, which – inter alia – should make it feasible to subsidise also sustainable summer comfort approaches. After notification of the law, which is expected till mid 2007, the detailed rules need to be worked out. The Austrian Energy Agency has been invited by the ministry to participate in this process and to contribute mainly on the revision of the subsidy scheme related to a reduction of cooling energy demand. It has to be stressed, however, that there might be considerable budgetary constraints, since the actual subsidy scheme is rather small (up to 5 million EUR per year). An extension of the scheme by the aspect of sustainable cooling as well as by an additional subsidy scheme for new construction would require a budget approximately three to four times higher.

5.3.2 Italian schemes for promotion of envelope and passive technologies

In Italy, experience and know-how gained during the project has been used during contacts with policy makers in order to support new legislation on energy efficient buildings, in particular regarding the reduction of cooling demand.

Mr. Edo Ronchi, former Minister for the Environment, presently member of the Senate, has prepared during 2006 a law proposal, (Disegno di legge. Norme per l’attuazione del protocollo di Kyoto con lo sviluppo delle fonti rinnovabili, dell’efficienza, dell’innovazione del sistema energetico e della mobilità), which has gained support by all the members of the Environment Commission of the Senate. eERG was invited by Mr. Ronchi and by the coordinator for energy of the government coalition, Mr. Paolo Degli Espinosa, to give advice (among others) on initiatives to lower energy consumption in buildings. The main suggestions retained in the Law Proposal and relevant to KeepCool were:

- As for set points temperatures, controls on the respect of the upper limit of 20 °C in winter should be reinforced, and adequate limits should be set for summer set points, in order to avoid unnecessary energy consumption, as required by the EPBD.
- Calculation methods for energy consumption should include winter and summer consumption, and calculate separately the useful energy demand (in order to give a rating of the performance of the building envelope) and final energy demand (in order to give a rating of the efficiency of the generation plant and use of renewable energy).
- Volumes occupied by insulation materials, attached greenhouses, solar chimneys for passive cooling, distribution systems serving ground exchangers and other passive tech-

niques should not be counted in the legal volume of the building and hence not undergo taxation.

- Urbanisation costs should be zero for new buildings with passive cooling features.
- Economic incentives should be given to the installation of a series of technologies, including air tight window frames and external solar protections.
- Energy efficiency retrofits of buildings should be promoted and energy efficiency improvements should be a condition for accessing incentives to retrofit.
- While extending Saving Obligation to the period 2010-2016 and raising its level, savings deriving from passive cooling measures (e.g. increasing thermal insulation, controlling solar radiation entering through glazed surfaces during summer, implementation of passive heating and cooling techniques), should be counted for a period of 20 years rather than for a period of 5 years as the other measures.

These type of measures to remove barriers to envelope and passive technologies were also suggested to Mr. Gianni Silvestrini in August and September 2006, after he has been appointed Energy Advisor to the Ministry for Economic Development, in charge of implementing EPBD. During meetings with him we underlined the high economic value of saving cooling energy, since it is saved at times (summer afternoons) when the system costs are highest (peak demand for the Italian electricity system occurs now in summer, and during the hottest weeks of summer 2003 the price of electricity went to extremely high values on the wholesale market in Italy as in France). In Law 311/2007, completing Law 192/2006 for the implementation of EPBD, some measures have been adopted:

- (paragraph 10) for buildings with useful surface above 1000 m², effective external shading systems will be compulsory.
- (paragraph 9) for locations where monthly average solar irradiation on a horizontal plane exceeds 290 W/m², mass per unit area of opaque surfaces should exceed 230 kg/m² (or a similar thermal behaviour be obtained by means of innovative techniques and materials). In order to limit summer energy demand, a check should be made that: external or internal shading is in place; external conditions and building geometry should optimise conditions for night ventilation; in case night ventilation would not be effective adequate mechanical ventilation means are installed, as are heat recovery systems when ventilation rates and hours of operation exceed certain specified values.

A likely follow-up of these initiatives should be a workshop with ESCOs, energy companies, manufacturers, General Directors of the Ministry for Economic Development and of the Ministry of the Environment to be held in June 2007 where Dr. Pagliano is invited to discuss methods to reward passive technologies via the Energy Saving Obligation and the Energy Efficiency Certificates (or White Certificates) schemes.

5.3.3 Andalusian funding scheme for sustainable energy projects, Spain

In Andalusia, there is a sustainable energy development funding scheme (Orden de 18 de Julio de 2005) where solutions for buildings that accomplish a energy consumption reduction of at least the 10% of the original energy consumption, are being funded.

With the Andalusian Energy Agency, the governmental body for energy issues and the regulatory body for this funding scheme directly participated in KeepCool, and included “sustainable cooling” projects into the energy efficiency category. Currently, this Plan is approved for the year 2007.

5.3.4 Bringing together relevant actors in Sweden

In parallel to actions targeted at market actors, the policy making and regulating authorities were also involved in KeepCool. In fact, the different regulations and recommendations that define summer comfort can originate the excessive use of artificial cooling if their formulation is not appropriate or if too low temperatures are used in reality. Also, building energy performance requirements impose limits to total energy use in buildings, meaning that any over-consumption in cooling implies savings in heating or ventilation. Thus, also here enforcement is a particularly important aspect. To address these issues, a policy dialogue was set up.

One important point was the definition of summer comfort which is defined mainly by the authority for the working environment (Arbetsmiljöverket, addressing in this case tertiary sector buildings) and the board for health and welfare (Socialstyrelsen, addressing residential buildings and some publicly used buildings like schools and hospitals). In the dialogue participated the HVAC professionals association, which produce guidelines for their members. Their interpretation of the requirements and their design and operation practices influence greatly the use of artificial cooling. The board responsible for housing and construction (Boverket), which establishes building thermal and air quality regulations also participates. The project KeepCool initiated in this way a dialogue between institutions that had never discussed this issue together and provided immediate results in the form of giving a better feedback to authorities on how the regulations and recommendations are applied and how they can be revised or better enforced. This initiative was highly appreciated and interest to continue the cooperation was stated.

5.3.5 Influence on the energy certification in Lithuania

In the year 2007, certification of energy efficiency in buildings has been implemented in Lithuania. In accordance with the requirements of European Union, energy input for heating and cooling (kWh/m²a) is calculated and buildings are attributed to one of the energy efficiency classes. At the present, energy input is only calculated for heating. After objective discussions with policy makers it is clear that in the next year technical documents of construction will be initiated, which should regulate energy input in buildings. The process will take time, but at this point we see that Lithuania moves forward.

5.3.6 First contacts made in Germany

First informal contacts to the German funding bank „Kreditanstalt für Wiederaufbau KfW“ and the German Energy Agency “Deutsche Energieagentur – DENA”. Up to now there is no concrete outcome of these approaches within the period of Keep Cool, but both contacts showed interest to implement sustainable cooling strategies for future campaigns and funding policies.

5.4 Recommendations for further European policies in this field

The main elements to foster the market penetration of sustainable summer comfort approaches in building industry need to be implemented at the national level:

- building codes with a strict minimum standard on useful energy demand for cooling and an incentive for the application of passive cooling systems;
- easy and reliable access to information and specialised consultancy for building owners and administrators;
- exemplary role of the public building sector;
- adaptation of existing subsidy schemes or new subsidy schemes that support (elements of) sustainable summer comfort.

There are, however, a number of opportunities for European policy to enhance sustainable summer comfort approaches. These will be described in detail in the following.

5.4.1 Check of building codes, energy certification and AC inspection

The EPBD gives a framework to the Member States for the implementation of policy instruments that lead to energy savings in the building sector. In translating the framework into concrete measures, the Member States have a relatively high degree of freedom which leads to very different approaches.

For the market penetration of sustainable summer comfort, the following instruments are crucial:

- Building code: Does the building code put pressure on building owners to reduce cooling demand, respectively does it give an incentive to use passive cooling technologies?
- Energy certification: Does the energy certificate display the cooling demand of the building in a visible way, i.e. is the useful energy demand for cooling an element for the determination of the energy efficiency classes? Is the use of passive cooling technologies mentioned in the certificate?
- Inspection of AC systems: How far does the energy advice in the frame of the inspection go? Does it relate to the mechanical AC system only or does it also include measures for the reduction of the cooling demand?

In order to enhance sustainable summer comfort, the European Commission should comprehensively check the above mentioned aspects of EPBD implementation and require adaptation from the Member States in case that these aspects have not been considered in a satisfactory way. Of course, necessary adaptation has to be based on the text of the EPBD, which in our opinion, however, gives sufficient basis in this context (reference of the overall energy performance of the building according to Annex I).

5.4.2 Comfort level as main influence factor

In particular, while checking the above mentioned instruments (building codes, energy certification, inspection of AC systems) the European Commission may promote a special attention by the Member States on the issue of comfort definition and its impact, as is laid down in the preamble of the EPBD:

> *"Moreover, displaying of officially recommended indoor temperatures, together with the actual measured temperature, should discourage the misuse of heating, air-conditioning and ventilation systems. This should contribute to avoiding unnecessary use of energy and to safe-guarding comfortable indoor climatic conditions (thermal comfort) in relation to the outside temperature."* (European Communities, 2003, p. L1/66).

The KeepCool project elaborates on this and confirms that the definition of comfort levels plays a crucial role in determining the energy consumption for cooling and the applicability of the sustainable summer comfort concept. The deployment of sustainable summer comfort and the construction of comfortable buildings is dependent on a correct application of the Adaptive comfort model in non-mechanically cooled buildings and of the Fanger model in mechanically cooled buildings, taking due account of the degree of flexibility allowed also in the latter. Beside the European Standard EN15251, which has been remarkably improved by the intervention of the KeepCool-team, the correct application of these two comfort models needs to be included also in design standards where design temperature levels are still mostly fixed. The implications of the potential use of the models are significant (for the full quotation of Dear and Brager (2002), see Section 3.3.1 above):

- In naturally cooled buildings, potential savings are up to 100% of the cooling energy that would otherwise be used by an air-conditioner to maintain fixed temperature set points;
- In mixed-mode buildings, the energy savings would be proportional to the difference between the upper limit of the Adaptive Comfort Standard, compared to typical set-points used in an air-conditioned building (approximately 23°C);
- In mechanically cooled buildings, the energy savings would be proportional to the difference between the set-point defined by the upper limit of the Fanger model and its application in ISO 7730, and the usual operating set-points (approximately 23°C).

However, in practice, the possibility to correctly apply the comfort models depends on:

- the regulation of employee protection (which usually is based on applicable norms);
- the perception of building owners on the comfort level required from customers (building owners usually assume that customers need air conditioning rather than summer comfort).

At the moment, both influence factors can act as barriers for the construction of a building that is run according to the Sustainable Summer Comfort concept.

The following activities of the Member States, promoted and supported at European level in order to aim at a certain degree of harmonisation, could support the achievement of both comfort and energy efficiency:

- Enact legislation and incentives schemes to take full stock of the possibilities offered by the Adaptive model in characterising comfort in non-mechanically cooled buildings, as it is now incorporated into the European Standard EN 15251.

- Enact legislation and incentives schemes to take full stock of the flexibility present in the Fanger model and its application in ISO 7730 (in mechanically cooled buildings). The adoption of light clothes (allowed or encouraged by dressing codes as in the case of Japan), low resistance chairs, and air movements via ceiling or desk fans would allow for occupants' comfort sensation at higher air temperatures (and hence lower energy consumption) than in the standard case without using these flexibility options.
- Include a description of comfort models and comfort classification in the curricula for designers and training courses for professionals who will be charged of providing the building energy certification.

5.4.3 Evaluation of the EEAP according to the EEE-ESD

Electricity consumption due to additional cooling loads is one of the most quickly increasing elements of the end-use energy consumption in most Member States. Any strategy to improve energy efficiency needs therefore to address this segment. The Directive on Energy End-use Efficiency and Energy Services (EEE-ESD) gives the framework for further development of energy efficiency policy in the Member States:

- In the frame of the implementation of the EEE-ESD, the Member States must prepare Energy Efficiency Action Plans (EEAP) which have to include also an estimation of the energy savings related to the implementation of measures.
- Article 5 of the EEE-ESD requires the Member States' public sector bodies and agencies to provide an exemplary role in improving energy efficiency.

In this context, the European Commission might support the Member States by the following activities:

- Comprehensive evaluation of the national EEAP-s with respect to measures that reduce energy consumption for cooling and information exchange between member countries on this issue;
- Development of guidelines for public procurement that take into account energy savings from sustainable summer solutions and compilation of best practice examples relating to the integration of energy efficiency issues – in this case of sustainable summer aspects – into public building administrations;
- Making available simplified procedures to evaluate the energy savings related to sustainable summer comfort (approach for a bottom-up assessment).

5.4.4 Research and Development

The European Union is a big player as refers to research and development (R&D). The "European Strategic Energy Technology Plan (SET-Plan)" will become a framework document for the future orientation of the European R&D policy in the energy (efficiency) sector.

Already the composition of the "European technology platforms in the energy field" demonstrates that energy efficiency in general and sustainable summer comfort in particular is perceived as a minor issue in the European energy-related R&D landscape. These platforms have made preparatory work for the development of the SET-Plan, but exclusively on supply-oriented topics such as zero emission fossil fuel power plants, hydrogen and fuel cells, photovoltaics etc.

In this context, the following activities at the European level are important:

- Making visible the R&D needs and opportunities in the field of energy efficiency in buildings, with a focus on sustainable summer comfort issues (e.g. through the formation of a European technology platform for envelope and passive cooling technologies);
- Increasing the share of demonstration, dissemination and monitoring activities in the frame of the European R&D programmes: a number of Sustainable Summer Comfort solutions are already market-ready, though their integrated design and coherent integration into the building still needs research and testing, including the interaction of the building elements, plants and occupants in real-scale objects. Therefore, the focus of R&D policy should shift from mainly technology development and demonstration to dissemination, integrated design approaches, and large, well designed monitoring campaigns. This shift in focus will in turn deliver feed-back for further development of technologies related to summer comfort because only application under real conditions can deliver information on applicability of technologies and the resulting further need for development.
- Promoting empirical studies on comfort perception in real, occupied buildings, conducting statistically relevant comfort surveys in mechanically cooled buildings, buildings that apply passive cooling technologies and in hybrid buildings. Preliminary studies (e.g. SCAT) show on a limited number of cases that the application of the adaptive comfort model to define a variable set-point in mechanically cooled buildings may be evaluated positively by occupants as for comfort perception, while at the same time reducing the energy consumption of these buildings (McCartney and Nicol, 2002). The thematic link to the issue of "healthy buildings" should also be investigated.

5.4.5 Real Estate appraisal

In the highly capitalised and dynamic real estate market real estate appraisal is an important control mechanism that regulates the direction of capital flows. In general, the energy performance of a building – and thus also the aspect of sustainable summer comfort – is not taken into account in real estate appraisal.

Valuation methods in the standards used in EU Member States were developed long before energy efficiency and energy certificates were discussed. Therefore, appraisers find it hard to account for new developments and market-driven aspects like energy efficiency and LCC within their calculations and valuation reports. A main reason why this field of interest has not yet been researched is probably because energy certificates and energy efficiency have a strong technical and facility management oriented research basis, but the economic aspects – which would be valuable for property valuation – seem to stand on a much more fragile foundation.

Since real estate appraisal is very much driven by standards and norms, the European Commission could intervene here and take influence on the further development of appraisal methods, e.g. by mandating the development of a CEN-standard on the integration of energy performance aspects in the real estate valuation methods.

6 Conclusions

The KeepCool project provided a good base for the market transformation from “cooling” to “summer comfort”, that is from demand for an energy-using action to demand for a service. It brought together the results of many research projects into one consistent approach for sustainable summer comfort, and developed understandable information material for the most important target groups. In addition, it contributed to European and national regulations that promote summertime energy efficiency with the help of passive cooling, and started with market implementation in eight European countries, delivering important experience on the success factors and barriers on the market.

Future actions in the field can use the results of our project for further market transformation activities: they can continue to tackle the identified market barriers, and by doing this, they can employ the dissemination principles that proved to be most successful during the course of KeepCool. A great opportunity to overcome the four identified barriers is given in the relevant EU Directives: in its introduction, the EPBD is explicitly calling for “strategies which enhance the thermal performance of buildings in the summer period” (European Communities, 2003, p. L1/66). In addition, the new Directive on Energy End-Use Efficiency and Energy Services (EEE-ESD) is setting energy saving targets for the European Union and the Member States, and requires an Energy Efficiency Action Plan (EEAP) as well as energy efficiency criteria in public procurement schemes from each Member State (European Communities, 2006). Both instruments allow for the broad implementation of measures that help to consolidate the passive cooling market, to support integrated planning and to make use of the newest standards in the design of cooling equipment. In turn, Sustainable Summer Comfort seems to be a very effective means to fulfil the requirements of the EEE-ESD, as it leads to a considerable and long lasting reduction of the energy (and especially the peak energy) consumption of buildings.

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