School of the Future
Towards Zero Emission
with High Performance Indoor Environment

Project number: 260102

Report
Selected Publications and Projects about
Energy Efficiency and Indoor Environment Quality

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ABOUT ‘SCHOOL OF THE FUTURE’

‘School of the Future’ is a collaborative project within the 7th Framework Program of the European Union in the energy sector. It started in February 2011 and will run for 5 years. The aim of the «School of the Future» project is to design, demonstrate, evaluate and communicate shining examples of how to reach the future high performance building level. School buildings and their primary users – pupils, the next generations – are in the focus of the project. Both, the energy and indoor environment performance of 4 demo buildings in 4 European countries and climates will be greatly improved due to holistic retrofit of the building envelope, the service systems, the integration of renewables and building management systems. The results and the accompanying research and dissemination efforts to support other actors dealing with building retrofits will lead to a multiplied impact on other schools and on the residential sector, since the pupils will act as communicators to their families. The user behaviour and the awareness of energy efficiency and indoor environment will be improved due to tailored training sessions.

Zero emission buildings are a main goal in various country roadmaps for 2020. The demonstration buildings within the project may not completely reach this level as the aim of the call is cost efficiency and multiplication potential. The retrofit concepts will, however, result in buildings with far lower energy consumption than in regular retrofits with high indoor environment quality – thus leading the way towards zero emission. They can be considered as schools of the future. Results from national examples of zero emission schools will complete the information used for developing the deliverables such as guidelines, information tools, publications and a community at the EU BUILD UP portal.

The project is based on close connection between demonstration, research and industry represented by the “design advice and evaluation group”. The proposal idea was introduced at the E2B association brokerage event with high interest which results in a consortium including well-known partners from the building industry.

SELECTED PUBLICATIONS AND PROJECTS ABOUT ENERGY EFFICIENCY AND INDOOR ENVIRONMENT QUALITY

Buildings represent one of the sectors that must significantly improve energy efficiency if today’s goals on reduced energy consumption and reduced emissions of greenhouse gases are to be met. Improved efficiency will necessitate improved building design as well as new energy systems and solutions, which may affect not only the buildings themselves, but also the indoor environmental conditions for their occupants.

Each year considerable numbers of school buildings of different types and age are retrofitted, but energy or sustainability issues beyond national requirements are usually not included, and no further optimisations with respect to energy savings, renewable energy use or indoor climate are conducted.
The aim of the project School of the Future (SoF) is to contribute to energy efficiency in school building retrofitting, and at the same time focus on the importance of healthy indoor environments. This report is meant to ease the work for people involved in school retrofitting by presenting existing knowledge, theories and experiences, concerning these topics.

The report includes a bibliography of publications about CO2 emissions related to energy consumption, effects of indoor climate on health and performance, and relations between energy efficiency and indoor environments. The most recent publications from the participating countries in the SoF project are reviewed, i.e. Italian, German, Danish and Norwegian publications. Some of these publications are written in English, but mostly they are written in national languages. Titles and abstracts of those publications are translated to English. Included are also some selected publications in English from other countries. Furthermore the report draws the attention to international projects relevant for school building retrofitting, and to programs and centres in the participating countries.

**PARTNERS WITHIN THE ‘SCHOOL OF THE FUTURE’ PROJECT**

<table>
<thead>
<tr>
<th>Country</th>
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1. PUBLICATIONS ABOUT ENERGY EFFICIENCY AND RELATED CARBON EMISSIONS

Publication in English


Abstract:
Within the methodological scope defined by ISO 14040, building LCA analyses can be divided between studies that focus on building materials and component combinations (BMCC) and studies of the whole process from cradle to grave (WPCG). This study uses multiple Chinese and international data sources to perform WPCG LCA analysis of ten buildings in and around Beijing. The data analysis was performed using EnergyPlus (version 5.0 from April 2010) linked with the operational module of the LBNL commercial building LCA model to demonstrate its feasibility for high-resolution analysis.


Publication in English


Abstract:
The Primary Energy Concept is a new method to provide information on primary energy efficiency and the environmental impact of different energy sources, energy conversion processes and energy transport systems. The method uses Primary Energy Factors (PEF) when calculating the amount of energy actually consumed or estimated to be consumed in a building. The method makes it possible to compare different and also complex energy chains consisting of several energy carriers by simply using the respective PEF values per delivered unit energy from each energy chain.

The paper describes the background of the method, definition of terms, the method itself, different EN-standards to implement the method and a simplified example; a comparison of three different energy chains. By using the “power bonus method” described in EN 15316-4-5 the results shows (i.a) that a combined heat and power plant might obtain a negative (zero) primary energy factor due to the production and export of electricity assumed to replace electricity with an high value of the PEF.
Publication in English

1.3. **Boermans, Thomas et al. 2011. Principles for nearly Zero-energy Buildings. Paving the way for effective implementation of policy requirements.**

Abstract:
A study of existing concepts and building standards are reported, presenting analyses of main methodological challenges and their implications for the nearly Zero-Energy Buildings definition, a set of principles is compiled, and their impact is assessed on reference buildings. Technological, financial and policy implications are evaluated. The report also contains an outlook on necessary further steps towards a successful implementation of nearly Zero-Energy Buildings.

Publication in Norwegian


Abstract:
Whilst energy consumption is a familiar theme in the building sector, CO₂ emission is a relatively recent issue. The two are obviously closely connected. In Norway, two questions often emerge: Since we have easy access to clean hydropower, aren’t Norwegian buildings quite clean to run? And is it not the case that reduction in energy consumption requires a further installation of materials and components that in them selves contribute to further emission? This article addresses these questions by looking at the single building and recent research on the effect of design. Studies of energy use in the life cycle span show that emissions from running the building are larger than emissions from building production.

In conclusion, the authors offer a set of recommendations for architects and designers, based on the fact that building form has a significant effect on energy consumption and therefore on CO₂ emissions:

- A compact, simple building form reduces energy losses through junctions and corners.
- Cold-bridges must be minimised, principally by ensuring a continuous layer of external insulation overall.
- The use of glass must be carefully considered. Use super insulating frames and panes and external sunscreens.
Zoning of functions according to temperature requirements helps lower energy consumption.

Material strategies must allow for cradle-to-cradle use. Design for demountability and recirculation.

Taking these measures into account early on in the design process should make the reduction of CO$_2$ emissions a challenge rather than a problem for architects and designers.

Publication in English


Abstract:
The author focuses on links between climate change and the building sector, and points out inadequacies of existing mitigation measures under conditions of increasing global consumption levels. It is argued that the current approach will lead to a series of weather-caused disasters, and that will lead to a call for quick action. The history of responses to major disasters is not a positive one, and a strategy of preparing contingency plans for use under emergency conditions is therefore suggested. A number of specific measures are proposed as means of rapidly reducing greenhouse gases.

Publication in English


Abstract

This paper represents a unique collaboration between experts in architecture and engineering from around the globe to evaluate the true potential to reduce CO$_2$ emissions from buildings. The result of this experiment in remote collaboration between Europe, USA, Japan and China, was a summary that was generated for the Holcim Forum workshop, “Reduce CO$_2$ – With technology to zero emissions.” This covers challenges of reducing emissions from building construction, operation and maintenance while also presenting an array of potential solutions. Here we expand on that work for the benefit of a broader audience.

The paper covers the overall problem of building emissions, both direct and indirect. It discusses the often-overlooked impacts of building material use. It also reviews the problems related directly to building CO$_2$ emissions and energy consumption, as
well as new analysis methods for better system design. Finally, many new processes are discussed that have the potential to drastically reduce building CO2 production to nearly zero. In summary we encourage new perspectives that increase the utilization of new methods and systems, thereby providing examples of technological groundwork that can incite new policy to reduce building CO2 emissions.

Publication in English

1.7. Ordóñez, Javier; Vijay Modi. Optimizing CO2 emissions from heating and cooling and from the materials used in residential buildings, depending on their geometric characteristics. Building and Environment Volume 46, Issue 11, November 2011, Pages 2161-2169

Abstract:

The objective of this research was to obtain the environmentally optimal design of a building with the following starting conditions: constant constructed surface, constant volume, square floor layout, and a variable number of floors. For this purpose, the study evaluated the impact of CO2 emissions stemming from the energy needed to maintain the building at a constant temperature of 19 °C in winter and 25 °C in the summer. Furthermore, one of the results was the CO2 emissions curve from the manufacturing of the materials used in the construction of the building and the building envelope.

The energy consumed to cool and heat the building was calculated by means of the simplified method specified in the ISO/DIS/13790 standard. The building was thus regarded as a monozone with the consequent simplifications. The matrix method was used to calculate the building’s structure for the purpose of obtaining the CO2 emissions from the concrete and steel needed to construct it. The result obtained was the curve representing the CO2 emissions, depending on building height. The source of these emissions was the energy consumption from heating and cooling as well as from the manufacture of construction materials. The results of the study indicated that the useful life of the building was a very important factor to take into account. The methodology used in this study could be used by building designers to design buildings with an optimal height for the reduction of negative environmental impacts.
Publication in English


Abstract:
Building school centers using industrialized technologies has been a common practice in Catalonia, Spain, since 2002. Over 200 public educational edifices have been assembled using these technologies, in order to provide the required number of schools in due time. These schools serve as examples of modern educational architecture and their building technologies have particular features compared to non-prefabricated ones. In this article these technologies are analyzed from a technical and sustainable point of view, in order to determine how they improve the quality of these buildings and reduce their environmental impact. A life cycle analysis has been carried out comparing the three main industrialized technologies and a non-prefabricated one. All of these technologies have weak points and this research recommends a new optimized technology based on them. Renewed current technologies could reduce both resources consumption and waste generation but would never be able to close the materials cycle as the recommended technology does.

Publication in English


Abstract:
This paper studies the way in which CO₂ emission levels are affected by different measures to reduce energy consumption in a building. A case study is presented which deals with a residential building in Navestad, a suburb of the Swedish city Norrköping. The building is supplied with district heating primarily delivered from a combined heat and power (CHP) plant. Three types of energy measures are studied: extra insulation, new types of window and the introduction of a heat pump. The first perspective is the city of Norrköping, with the system boundary encompassing the residential building and the CHP plants. A second worst case scenario is then presented: a Nordic perspective in which electricity produced in coal condensing power plants is assumed to cover the marginal electricity production. With the former perspective, the measures extra insulation and new windows reduce the CO₂ emissions, and with the latter both measures increase the CO₂ emissions. The measures extra insulation and new windows are ranked, with respect to cost for the first perspective, using a cost reduction curve for CO₂ emissions. In the paper, costs from the ExternE research project are also used.
Publication in English


Abstract:
A literature survey on buildings’ life cycle energy use was performed, resulting in a total of 60 cases from nine countries. The cases included both residential and non-residential units. Despite climate and other background differences, the study revealed a linear relation between operating and total energy valid through all the cases. Case studies on buildings built according to different design criteria, and at parity of all other conditions, showed that design of low-energy buildings induces both a net benefit in total life cycle energy demand and an increase in the embodied energy. A solar house proved to be more energy efficient than an equivalent house built with commitment to use “green” materials. Also, the same solar house decreased life cycle energy demand by a factor of two with respect to an equivalent conventional version, when operating energy was expressed as end-use energy and the lifetime assumed to be 50 years. A passive house proved to be more energy efficient than an equivalent self-sufficient solar house. Also, the same passive house decreased life cycle energy demand by a factor of three – expected to rise to four in a new version – with respect to an equivalent conventional version, when operating energy was expressed as primary energy and the lifetime assumed to be 80 years.

Keywords: Life cycle; Operating energy; Embodied energy; Low-energy; Solar house; Passive house

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Publication in Norwegian


Abstract:
The report gives an overview of the structure of the calculation model and shows some results from applications. This third version model includes a module for early phase assessments of emissions from materials. Further this third version has got a user interface which makes it easier to calculate several alternatives within the same
project. Emission function for electricity is introduced, taken into account technology development and policy decisions, goals and instruments.


Publication in English

1.12. Theodosiou, George; Christopher Koroneos, Nikolas Moussiopoulos. Alternative scenarios analysis concerning different types of fuels used for the coverage of the energy requirements of a typical apartment building in Thessaloniki, Greece. Part I: Fuel consumption and emissions.
Building and Environment 42 (2007) 1522–1530

Abstract
This paper focuses on the analysis (concerning energy and environmental performance) and comparison of different types of fuel intended either for direct use (e.g. domestic boiler combustion) or indirect use (production of electricity that will be consumed) in order to satisfy the energy requirements of a typical apartment building in Thessaloniki, Greece. The energy requirements that are being examined are: space heating, water heating, kitchen and cooking appliances, lighting and other various electrical appliances. For the purposes of this analysis an apartment building model has been designed that simulates combinations of these operations sorted in five scenarios in proportion with the fuel being used and the way electricity is generated. The analysis' obtained results concern: pollutant emissions per kg, kWh or m³ of the fuel being used, daily total emissions that correspond to the estimated fuel required to satisfy the energy needs of the apartment building and the financial comparison of all scenarios.

Publication in English

ISBN: 978-3-0346-0780-3

Abstract:
Net zero energy and plus energy buildings presented in this book indicate how an equalised annual energy balance can be achieved by bringing together energy efficient architectural design and local use of renewable energy sources. This publication was produced in the context of collaboration between experts of the International Energy Agency (IEA) in the framework of the programmes Solar Heating and Cooling (SHC, Task 40) and Energy Conservation in Buildings and Community Systems (ECBCS, Annex 52).
2. PUBLICATIONS ABOUT INDOOR CLIMATE AND PUPILS’ PERFORMANCE

Publication in English


Abstract:
In climate chamber tests different combinations of indoor environmental parameters were tested for their interactive effect on 56 students. The combination of parameters concerned each two levels of operative temperature (23.5 and 28 °C), noise (52 and 60 dB(A)) and pollution load of indoor air (absent and present). The combinations were sequentially changing during the experiment. During each combination the persons did performance test consisting of simulated office work and questionnaires to environmental perception and adverse health affects. In comparison to the reference condition with low temperature and noise and no pollution load performance of the test persons fell off significantly in all combinations with at least two negative parameters including warm operative temperature. Self-estimated performance was significantly worse in any other combination than reference condition and it was worst in combinations with a high noise level. But the results of the performance test didn’t approve this great impact of noise level. The persons also overestimated the negative effect of the other parameters. Bad indoor air quality was the parameter which was accepted more easily by the persons than the other adverse parameters.

Publication in English

2.2. Clausen, G.; Wyon, D. 2008. The combined effects of many different indoor environmental factors on acceptability and office work performance. HVAC & R Research (ISSN: 1078-9669), 14, 103-113

Abstract:
In the tests with four groups with each about 25 students investigated the influence of all possible indoor environmental parameters on subjective assessment, self-reported performance and objective measured performance by means of simulated office work. One group was exposed two hours to a set of poor environmental conditions (bad artificial lighting and almost no daylight, a high noise level from a busy street, 27 °C operative temperature and polluted supply air). A second group briefly was exposed to these six conditions and the opposite good conditions (improved lighting and a daylight view out, barely audible traffic noise, operative temperature of 22 °C and clean supply air). In addition to that the annual cost of
improving each of the first six conditions was represented as a percentage of the total sum of improving all conditions. The persons were asked for the improvements they preferred, up to 50% of the budget. In the third group each person was randomly paired with a person from the second group. Each pair was exposed to the conditions selected by the second-group subjects. The fourth group was exposed only to the improved conditions. The results showed that subjective assessment of indoor environment and self-reported performance was better in the fully-improved conditions for all persons and the partly-improved conditions for these persons, who have themselves chosen the conditions. Though there was no difference in measured performance between the groups.

Publication in English


Abstract:
This work shows the results of a field study about environmental comfort investigations in classrooms. Thermal, acoustic, visual and air quality aspects were analysed in a number of classrooms—13 classrooms at four different high schools in Torino, Italy. The investigations were carried out during the heating period. This paper focuses on thermal comfort, which may have a significant effect on the students’ performance, in terms of attention, comprehension and learning levels. The measurement campaign consisted in measuring the thermal environment parameters — air temperature, means radiant temperatures, air relative humidity and air velocity. Through these data, the thermal comfort Fanger’s indices were calculated, the actual people clothing and metabolic rate being known. The subjective survey basically investigated the thermal environment acceptability and preference. Moreover, a judgement based on the typical seven point thermal sensation scale was also asked. The judgements about the thermal environment were compared with the results of the field measurements. Moreover, the subjective mean votes were compared with the thermal environment perceptions in terms of acceptability and preference.
Publication in English


Abstract:
The paper summarized over 300 peer-reviewed literatures on Indoor Air Quality, ventilation, and building-related health problems. There is evidence that many school districts in the US and other countries have significant indoor environmental problems. For example, several ventilation rate measurements of schools in the US and in Europe were examined and it emerged that the ventilation in many classrooms is inadequate. Also CO2 concentration measurements in schools suggest that a significant proportion of classrooms probably do not meet the standard for minimum ventilation rate. Furthermore, they had a look at some indoor pollutants. The most commonly measured pollutants in schools were total volatile organic compounds (TVOC), formaldehyde (HCHO), and biological contaminants. Although HCHO levels were generally low, recent research suggests that even low levels may lead to an increased risk of sensitization to allergens. Particularly high TVOC concentrations indicate the presence of strong VOC sources and/or low ventilation. There is also evidence that low ventilation rates and other building characteristics can lead to increased incidence of respiratory diseases caused by viruses. No references were found for airborne viral measurements in schools, but total airborne bacteria have been reported in a number of studies.

The relationship between health symptoms, ventilation and other indoor environment factors in schools were investigated. The investigations show that although results from the few studies in schools have been inconsistent in associating ventilation rates or CO2 concentrations and symptoms, a broad literature review for indoor environments more generally suggests a consistent relationship.

Publication in Dutch


Abstract:
A study was performed to analyse whether a ventilation control based on CO2 is a good way to improve the indoor comfort in classrooms. The study consists of two sub-studies. In the first study, the performance of four demand driven ventilation systems based on CO2 concentration is analysed. The results show that the demand-driven ventilation can significantly improve the situation in the classrooms. The control of the systems needs some improvements though. The second part of
the research focuses on the impact of demand-controlled ventilation on the cognitive performance of students. The above report describes the results of the second sub-study.

The aim of the present sub-study was to determine whether pupils of elementary schools show a better cognitive performance in classrooms with demand-controlled ventilation than in classrooms with standard ventilation conditions. The aforementioned standard ventilation conditions are similar to conventional ventilation conditions in which CO₂ concentrations in a classroom greatly increase as the morning or afternoon progresses, because the manual ventilation devices are used insufficiently. Investigated was with a number of neuro-psychological tasks, whether the cognitive performance of pupils in grade 7 and 8 of the elementary school get worse during the day due to increasing CO₂ concentration. With the demand-controlled ventilation by means of a CO₂ concentration control a proper ventilation is achieved and the CO₂ concentration in the classroom was kept at an acceptable level. The survey was structured so that each student served as his own verification, thus the statistical information value (statistical power) is considerably higher than when the test is run only once in a cross-sectional study of a group. The study involved two groups of students in grade 8. One group has made the first test under standard air conditions, the other group began with the questions under demand-driven ventilation. The next day, the two groups made the tests under the other ventilation conditions. The same test was made with students in grade 7. The aim was to minimize the statistically significant increase effect.

Taking into account differences in test sequence, the results of the study show that students at the end of the morning or afternoon make significantly less math and language mistakes in demand-controlled ventilation than under standard conditions of ventilation with increasing CO₂ concentrations. On average, students make 5.34 language errors and 1.98 miscounting errors in demand-controlled ventilation, while the students errors under increasing CO₂ concentrations averaged to 5.64 language errors and 2.44 calculation errors. In short, this study shows that the students of these tests actually performed better in well-ventilated classrooms.

Publication in English


Abstract:

The survey investigated the concentration of bacterial markers in seven classrooms in occupied and non-occupied moments. To do this, dust was collected from outside air and from the same rooms during the week and at weekends. In addition to this, concentration of carbon dioxide, temperature and humidity were measured. The survey discovered that the concentration of bacterial markers were 6 times higher during occupation than in non-occupied phases. The strongest correlation was found
between the concentration of carbon dioxide and bacterial markers, where carbon dioxide concentration was about 1000 to 1700 ppm in occupied rooms and 400 ppm in non-occupied rooms. The authors hence conclude that the children were liable for the higher concentration of bacterial markers, coming either directly from the pupils or indirectly, by stirring up dust from the floor. The results also indicate that higher air change rates can reduce the pollution of indoor air with bacteria and therefore reduce the possible health impacts on pupils.

Publication in English


Abstract:
The test investigated the relationship between the ventilation rate and the increase of chronic diseases as well as the productivity of occupants. For this, dwellings, schools and offices in different European and Northern American countries were tested. A study showed that in the course of time the air-exchange rate has changed. The transition to lower air-exchange together with reduced infiltration rates ended in less fresh air for occupants. Truly, analysis found out that there is a relationship between the ventilation rate and the productivity of office workers. With the increase of ventilation the productivity of office workers and the learning performance of pupils raised. Also the impacts on financial implications were tested and showed that with the increase of ventilation in offices, schools and dwellings a gain of 81,000 DALYs (Disability Adjusted Life Years)/year, at a cost of 18,000 Euro could be reached. The test comes to the conclusion that ventilation has to be replaced by an air-exchange rate which is based on complete health than on odour abatement.

Publication in English

Indoor Air, 21, 121–131

Abstract:
This study in one hundred elementary schools with mechanical ventilation investigates the relationship between classroom ventilation rates and academic achievement. The common ventilation rate for each school was estimated from CO₂ concentrations measured in one classroom per school. Performance level of the pupils was gained from standardized test scores. The analysis of the data showed a linear regression between the ventilation rates and the academic achievement of the pupils. For a 1 l/sP bigger ventilation rate the number of pupils, which gained a satisfactory score or better, increased by 2.7 % for reading tests and 2.9 % for math
tests. The authors note that these results are limited to ventilation rates between 0.9 and 7.1 l/s, because 87 of the 100 investigated classrooms had ventilation rates below recommended guidelines (ASHRAE Standard 62).

Publication in English


Abstract:
This study investigates whether daylight and other aspects of the indoor environment in elementary school student classrooms have an effect on student learning, as measured by their improvement on standardized math and reading tests over an academic year. The study uses regression analysis to compare the performance of over 8000 3rd through 6th grade students in 450 classrooms in the Fresno Unified School District, located in California’s Central Valley. Statistical models were used to examine the relationship between elementary students’ test improvement and the presence of daylight in their classrooms, while controlling for traditional education explanatory variables, such as student and teacher demographic characteristics. Numerous other physical attributes of the classroom were also investigated as potential influences, including ventilation, indoor air quality, thermal comfort, acoustics, electric lighting, quality of view out of windows, and the type of classroom, such as open or traditional plan, or portable classroom. From the standardized test it was found that every issue increasing problems with glare (for example no blinds at the windows or daylight from east) derogates performance, and having a good view to the outside, esp. to vegetation improves performance of the pupils. There was also found that performance decreased in rooms with a higher daylight level. But this was not due to the lighting quality or a different thermal comfort in these rooms, but due to a worse acoustic and more noise from outside through open windows.


Publication in English


Abstract:
The experiment investigated physiological and psychological reactions, performance and fatigue under the different combinations of indoor quality. 15 college-aged subjects of both genders were exposed five hours to different levels of humidity (30
and 70%), local air (with and without) velocity and illuminance (400 and 1200 lux). Room temperature was set to 25°C.

There were more complaints about eye dryness and visual fatigue and with local air velocity independent of air humidity and in all cases with low humidity. Complaints about eye dryness were higher with local air velocity although skin moisture was quite the same. High illuminance caused no physiological and psychological reaction, but measured performance was better with these conditions.

Publication in English


Abstract:
A experiment evaluated the effects of improvement of operative temperatures (28 and 25°C and 28°C), illuminance (400 and 750 lx) and with or without traffic noise on occupant’s performance. Performance of the ten men in the test chamber was estimated with a triple-digit multiplication test. The persons also voted satisfaction with indoor environment, the subjective symptoms of fatigue and self-estimated performance. When they were asked what kind of factor they wanted to improve the subjects gave priority to thermal and acoustic environment rather than lighting environment. The self-estimated performance was higher with high occupants’ satisfaction and lower with complaints about fatigue. The general rate of fatigue was higher with high temperatures and traffic noise. The effect of better illuminance on fatigue and self-estimated performance was not so evident. There was no significant difference in measured performance between the tested variants, but test scores were better in each of them compared to the control conditions (warm, noisy and worse illuminance).

Publication in English


Abstract:
The test investigated the physiological mechanisms of thermal discomfort and its effects on health and human performance. Twelve persons executed typical office tasks and neurobehavioral tests in two different thermal conditions (22 and 30 °C). The persons were also asked for their subjective estimation. Physiological parameters like heart rate or oxygen saturation in blood were measured. The results show several differences when the subjects felt warm. They assessed the air quality
to be worse, reported increased intensity of SBS symptoms, expressed more negative mood, and were less willing to exert effort. Task performance decreased while their heart rate, respiratory ventilation increased significantly and tear film quality was reduced. No effects were observed on salivary biomarkers. The authors conclude from their investigation that the negative effects of high temperatures on health and performance are caused by physiological mechanisms.

Publication in German


Abstract:
In this field study the performance of pupils in several primary school around Stuttgart (Germany) was investigated. The results were compared for pupils working in rooms with different acoustic conditions (reverberation time and speech intelligibility). Tests were made in the fields of comprehension, memorizing and assimilation of linguistically information. In addition to that the pupils were asked for their noise load and overall comfort. In order to rule out any cross interactions, they were also asked for they native language and social environment. The results of the investigation show a clear negative effect of bad acoustic conditions in the classrooms on the performance of the pupils, if the task was depended on speech intelligibility. Categorization of phonemes was performed significant worse with bad reverberation time whereas memorizing of pictures was not affected by that. The pupils also estimated a higher noise load and a worse overall comfort in these rooms.

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Publication in English


Abstract:
An intervention study was carried out in eleven elementary schools in Trondheim, Norway. Three schools with poor ventilation standard, four schools with carpets, and four reference schools participated. Carpets were replaced by vinyl flooring and the poor ventilation systems were upgraded. Altogether 1100 children aged twelve to thirteen years and 400 teachers were all included in the study. The baseline registration of health related symptoms were performed during January/February 1997. The questionnaires were repeated, after interventions, in February 1998 and
1999. The questionnaire used corresponds to questions in the Örebro questionnaire, but was adjusted to be performed with three repetitions during two weeks. In addition, a questionnaire on symptoms and asthma management to identify hypersensitive children was used in 1998 and 1999. Compared to reference schools the results from the intervention schools showed that the number of health related symptoms were reduced for both children with and without hypersensitivity.

Publication in English


Abstract:
To assess whether school environments can adversely affect academic performance, a review of scientific evidence relating indoor pollutants and thermal conditions, in schools or other indoor environments, to human performance or attendance was made. Evidence for direct associations between these aspects of indoor environmental quality (IEQ) and performance or attendance was critically reviewed. Secondarily, a summary of, without critique, evidence on indirect connections potentially linking IEQ to performance or attendance was written. Regarding direct associations, little strongly designed research was available. Persuasive evidence links higher indoor concentrations of NO2 to reduced school attendance, and suggestive evidence links low ventilation rates to reduced performance. Regarding indirect associations, many studies link indoor dampness and microbiologic pollutants (primarily in homes) to asthma exacerbations and respiratory infections, which in turn have been related to reduced performance and attendance. Also, much evidence links poor IEQ (e.g. low ventilation rate, excess moisture, or formaldehyde) with adverse health effects in children and adults and documents dampness problems and inadequate ventilation as common in schools. Overall, evidence suggests that poor IEQ in schools is common and adversely influences the performance and attendance of students, primarily through health effects from indoor pollutants. Evidence is available to justify (i) immediate actions to assess and improve IEQ in schools and (ii) focused research to guide IEQ improvements in schools.
Publication in German


Abstract:
In an investigation with 152 pupils the effect of good and bad air quality on alertness was tested in classrooms with natural ventilation. Good air quality was defined with carbon dioxide level of about 900 ppm, bad air quality with levels over 3000 ppm. In addition to the carbon dioxide level, air temperature and relative air humidity was measured. The test was done with an alertness-stress-test (d2) in two different studies, each study with another test design either to rule out effects of learning or bad motivation. In both studies the results were significant better with good air quality, but the effect in the second study was not as great as in the first one. The author recommends that the reason may be discouragement of the pupils due to a third iteration of the test (test-design to rule out effects of learning). But the averaged indoor air temperature was also about 1.5 degree higher in the second study.

Publication in English

ASHRAE J., 48, 22–28

Abstract:
The study investigated the effect of high indoor temperatures and bad indoor air quality on the performance of students. The studies were done in six identical class rooms equipped with HVAC-systems in a real school in Denmark with pupils aged from 10 to 12. In the first three transits (two in summer, one in winter) outdoor air supply was changed from 3 to 9 l/s*person, resulting in 800 and 1300 ppm carbon dioxide concentration. In another two transits (both in summer) indoor temperature was changed from 23.6 to 20 °C and from 24.9 to 21.6 °C. In all variations the performance of the pupils was tested with short exercises in reading, maths etc. implemented in a usual school day. Results show higher performance in work speed with higher ventilation rates and lower temperatures due to work speed. Within all significant test results performance increases 14 % with doubling air change rate and 4% with a 1 K lower indoor temperature. The results show no impact of indoor environment variations on the number of errors in the tests.
Publication in English


Abstract:

The tests with 30 students in an office investigated the effect of high temperatures and noise on acceptability of indoor environment, performance and SBS-Symptoms. In the tests three levels of air temperature (22, 26 and 30°C) and two levels of noise (35 and 55 dB(A)) were combined. During the exposure the persons had to do several tests, like addition, proof reading, typing and a creativeness-test. They were also asked for their self-estimated performance. With raised temperatures the thermal acceptability and self-estimated performance decreased and perceived air quality and SBS-Symptoms increased. With a higher noise level the persons also had more difficulty in concentration but self-estimated performance was equal to the lower noise level. In the objective measured performance there was a great difference between the several tasks. The performance in typing and reading was higher in noise but performance in the addition task decreased by 3%. Above that, persons who felt warm made about 50% more errors in the addition task. Though there was a significant interaction between the effects of warmth and noise. The effect of warmth on the error rate was not so great with a high noise level.
3. PUBLICATIONS ABOUT ENERGY EFFICIENCY AND INDOOR ENVIRONMENT

Publication in English


Abstract:
The report provides a guide to daylight and solar shading systems that can be applicable for zero emission buildings at high latitudes. The report includes a general introduction to daylight in buildings, an overview of technological solutions as well as a discussion related to the interaction between daylighting systems and other building components. The work has been performed within The Research Centre on Zero Emission Buildings (ZEB), work package 2: Climate-adapted low-energy envelope technologies.

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Publication in English


Abstract:
Symptoms, signs, perceptions, and objective measures were studied in university buildings. Two problem buildings with a history of dampness and complaints were compared with two control buildings. Health investigations among university staff were performed at the workplace (n = 173) including tear film stability [non-invasive break-up time (NIBUT) and self-reported break-up time (SBUT)], nasal patency (acoustic rhinometry), nasal lavage fluid analysis [NAL: eosinophil cationic protein (ECP), myeloperoxidase (MPO), lysozyme and albumin] and atopy by total serum IgE and IgE antibodies (Phaidiatop®). Exposure assessment included inspections, thermal and atmospheric climate at 56 points modelled for all work sites. Multiple regressions were applied, controlling for age and gender. Exposure differences between problem buildings and controls were small, and variations between rooms were greater. Workers in the problem buildings had more general and dermal symptoms, but not more objective signs than the others. Adjusted day NIBUT and SBUT increased at higher night air temperatures, with B (95% CI) 0.6 (0.04–1.2) and 1.3 (−0.02 to 2.5), respectively. Higher relative humidity at mean day air temperature <22.1°C was associated with adjusted NIBUT and SBUT, with B (95% CI) 0.16
(0.03–0.29) and 0.37 (~0.01 to 0.75), respectively. Air velocity below recommended winter values and reduced relative humidity in the range of 15–30% were associated with dry air and too low temperature.


**Publication in Italian**

**3.3. Bianchi, F.; M. Altomonte, M. E. Cannata, G. Fasano, 2009. Definition of indexes and energy need levels of the different energy uses in primary and secondary schools.**


**Abstract:**

The study is focused on the analysis of different school buildings, located in different Italian climatic zones. The data refer to effective energy consumption of the school buildings and include thermal and electric energy uses, energy uses are then normalised respect to relevant indicators. A main outcome of the study is the high inertia of public administrations in responding to the requested information. About the 90% of the contacted administration did not contribute and most of the information was collected through internet.

**Keywords:** Energy performance, benchmark indexes


**Publication in English**


*Indoor Air 14, 243-257.*

**Abstract:**

The scientific literature on health effects from dampness in buildings, including mite exposure over the period 1998-2000 has been reviewed by an European group (EUROEXPO) of eight scientists in experience from medicine, epidemiology, toxicology and engineering. Forty studies deemed relevant have been the foundation
for the conclusions. Dampness in buildings is a risk factor for health effects among atopics and non-atopics both in domestic and in public environments. However, the literature is not conclusive in respect of causative agents, e.g. mites, microbiological agents and organic chemicals from degraded building materials. There is a strong need for more multidisciplinary studies including expertise from all relevant areas. A general conclusion from the work was that there is a strong need for multidisciplinary reviews in scientific journals of articles dealing with associations between indoor environmental factors and health effects. PRACTICAL IMPLICATIONS: There is good evidence for a true association between dampness in buildings and health. As the causative factors behind this association are not known, the main focus in practical investigations should be on finding out and remediate the reasons for the humidity problem.


Publication in English


Abstract:
Several factors, such as functionality, area efficiency, energy demand, technical systems, materials, etc., influence the environmental load of a building. When planning a complex building, people with different competences and skills are needed to optimise different elements to find a suitable, holistic solution. A synergy effect of various actors’ skills is achieved when the planning process is successful. A Norwegian demonstration building, the Borgen Community Centre, is used to exemplify objectives and strategies when aiming for sustainable building. Some results of building performance analysis are also described.

Keywords: Sustainable building; Planning process; Building design; Environmental assessments

Publication in Norwegian

Miljøvennlige skoleanlegg. Thematic booklet published by the
Norwegian Directorate for Education and Training. ØkoBygg P.nr:
6141

Abstract:
Presentation of five schools connected to EcoBuild, a Norwegian change-over
programme for sustainable building. Some analyzes carried out in planning phases
are summarized. Further the booklet contains strategies to obtain a healthy indoor
environment with low energy consumption, and criteria used in assessing indoor
environment, functionality and esthetical concerns.
Free download: http://www.skoleanlegg.utdanningsdirektoratet.no/id/1131

Publication in Italian

buildings and energy benchmark for school buildings typologies.
Edifici tipo, indici di benchmark di consumo per tipologie di edificio,
ad uso scolastico (medie superiori e istituti tecnici. applicabilità di
tecnologie innovative nei diversi climi italiani) Report RSE/2010/190 –
National Energy research program funded by the Ministry of
Economic Development pp. 177

Abstract:
The publication provides energy benchmark indexes for school buildings, with
particular reference to secondary schools. In a next phase the analysis was focused
on technical secondary school buildings. The activity was carried out through two
parallel actions:
A monitoring campaign of thermal and electric energy uses based on annual or,
when available, monthly data. The campaign was carried out on more than one
hundred school buildings in the Piemonte (North West of Italy) region. Dynamic
simulation study to assess the thermal and electric energy demand using reference
buildings selected during the monitoring campaign.

Keywords: Energy consumption, benchmark analysis, energy savings

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ConsumiEnergetici/7%20polito.pdf
Publication in English

Paper published in Energy and Buildings 40 801-809

Abstract:
A field survey was carried out in order to collect, elaborate and analyse data concerning the actual energy consumption for space heating of a sample of about 140 buildings (120 high schools) in the Province of Torino (Italy). The buildings were equipped with heat meters. For each building the primary energy consumption, the metered supplied thermal energy, the daily and seasonal operating periods and the climatic data of the site were monitored. The energy consumption data were analysed in order to compare different buildings and different heating seasons. The study aimed at evaluating a specific energy performance indicator related to space heating for each building, to be used to establish benchmark values in heat energy service contracts, to predict heat energy consumption or to verify the increasing/decreasing of the actual consumptions in future heating seasons with respect to the benchmark value. The method also help identifying the buildings with poor performance and in need for in depth diagnoses and audits.

Keywords: Energy consumption; Operational rating; Energy performance indicator; School buildings

Publication in Norwegian


Abstract:
The paper gives a description of the first Norwegian passive house school, the design and building process and result from energy calculations.

Abstract:
Objectives: The aim was to study relationships between symptoms compatible with sick building syndrome (SBS) on one hand, and different indicators of building dampness in Swedish multi-family buildings on the other. Methods: In Stockholm, 609 multi-family buildings with 14,235 dwellings were identified, and selected by stratified random sampling. The response rate was 77%. Information on weekly symptoms, age, gender, population density in the apartment, water leakage during the past 5 years, mouldy odour, condensation on windows, and high air humidity in the bathroom was assessed by a postal questionnaire. In addition, independent information on building characteristics was gathered from the building owners, and the central building register in Stockholm. Multiple logistic regression analysis was applied, and adjusted odds ratios (OR) were calculated, adjusted for age and gender, population density, and selected building characteristics. Results: Condensation on windows, high air humidity in the bathroom, mouldy odour, and water leakage was reported from 9.0%, 12.4%, 7.7% and 12.7% of the dwellings, respectively. In total 28.5% reported at least one sign of dampness. All indicators of dampness were related to an increase of all types of symptoms, significant even when adjusted for age, gender, population density, type of ventilation system, and ownership of the building. A combination of mouldy odour and signs of high air humidity was related to an increased occurrence of all types of symptoms (OR = 3.7-6.0). Similar findings were observed for a combination of mouldy odour and structural building dampness (water leakage) (OR = 2.9-5.2). In addition, a dose-response relationship between symptoms and number of signs of dampness was observed. In dwellings with all four dampness indicators, OR was 6.5, 7.1, 19.9, 5.8, 6.1, 9.4, 15.0 for ocular, nasal, throat, dermal symptoms, cough, headache and tiredness, respectively. Conclusion: Signs of high air humidity, as well as of structural building dampness, are common in multi-family buildings in Stockholm. Reports of building dampness in dwellings is related to a pronounced increase of symptoms compatible with the SBS, even when adjusted for possible confounding by age, gender, population density, and building-related risk factors.

Publication in Danish


Abstract:

Pilot study on heating, ventilation and lighting qualities.

This report presents the first results of the "Programme for Energy Efficient Schools". The aim of this research programme is to provide the necessary basis for the design and operation of energy efficient schools of the future. Special efforts were made to develop methods for reducing energy consumption for lighting and ventilation also emphasising the creation of a healthy and stimulating indoor climate and at the same time incorporating the requirements to the school of the future.

The main purpose of the present investigations was to survey the energy consumption and assess the energy saving potential in a number of schools. A number of promising and innovative ways of ventilating classrooms was identified and analysed which will be implemented in the immediate future. Furthermore a brief outline of the daylight conditions in some typical schools is presented. The final chapter of this report deals with new trends in teaching and class work organisation and some general trends in the design of future schools.

Interdisciplinary and project-oriented teaching methods require more flexibility and more focus on the individual pupil. A pupil will participate in many different activities in the course of a day with special requirements to space, installations and lighting conditions. The scope for flexibility is particularly in focus as the danger exists that too flexible solutions become confusing and useless. Key words for some general trends in the physical interpretation of the Danish Primary Education Act are: flexibility, changeability, multi-functionality, more activities in the same room and larger rooms.

Publication in English


Abstract:

Environmental design principles are most effective when considered during the earliest most conceptual stages of the building design process. This article presents a design guideline in several steps to get a building design with minimized energy consumption. The article is based on work from a two years research project using computer simulations of energy and indoor environmental performance. A number of
examples help to illustrate the concepts and its integrated building elements. The article gives an overview of different energy related issues in the early design phase. Estimates of the effectiveness of different measures can help in the early design phase to get advice on the applicability of different energy efficiency strategies, which can form the basis for further detailed development of certain design aspects.

Keywords: Energy-efficient Design, Office Buildings, Design Strategy


Publication in English


Abstract:

Most ventilation regulations and standards are descriptive, meaning that they require ventilation flow rates which are assumed to dilute pollutants to acceptable concentrations. The required ventilation flow rates differ considerably between regulations and standards worldwide. This paper compares regulations in Scandinavia. These countries should be quite similar with respect to culture, building tradition, climate etc. In spite of similarities, the difference in required or recommended outdoor air flow rates is significant between the countries. A possible explanation may be uncertainties about indoor air quality and the necessary level of ventilation, in combination with different views on the balance between indoor air quality and energy use.

Publication in English


Abstract:

This paper presents collected occupancy data for 58 rooms, of which 56 are cellular offices, in a Norwegian office building. The data covers a time period of approximately three and a half months. Many modern office buildings have demand controlled ventilation (DCV) systems. Optimal design requires knowledge about how the building will be used. Taking into account that all rooms are not occupied simultaneously gives the opportunity to decrease the size of central components of a DCV system. The presented results for occupancy include both mean values and how occupancy is distributed over time and between different groups of occupants. The results show that the maximum occupancy factor in the building, with all rooms included, is below 0.5.

36
Publication in English


Abstract:
The objective of this study is to determine the potential energy savings and thermal comfort benefits of exposing concrete in the ceiling to the indoor air as an alternative to suspended ceiling. The performances were assessed through monitoring of room air and surface temperatures in an office building in operation, and simulation of different scenarios with a calibrated building simulation model. In this study, it is shown that the simulation program ESP-r is capable of simulating an advanced controlled office building in operation with good agreement with the measurements. The results presented in this paper indicate that exposed concrete in the ceiling both reduces the number of hours with excessive temperatures considerably and create a better and more stable thermal environment during the working day. Also, exposed concrete increases the achievements of utilizing night free cooling significantly. However, by removing the suspended ceiling, only minor annual heating energy savings are achieved.

Publication in German


Abstract:
Report of the holistic energy efficient retrofit of a school building in Stuttgart-Plieningen. The three building parts of the school built in 1936, 1957 and 1970 have been retrofitted with external thermal insulation and at some parts internal insulation, windows with low-e-coated glazing, insulation on the ceiling to the attic realised by pupils and teachers, a new lighting system including daylight dependent control in some classrooms and a new heating system that is combined of a gas condensing boiler and a low temperature boiler, new radiators and new heating pipes. The heating energy consumption could be reduced from 200 kWh/m²a to 49 kWh/m²a. Before, the heating consumption could be reduced by a long-term control system and management and motivation measures from 382 kWh/m²a to 210 kWh/m²a.

The project has shown that the heating energy consumption of school buildings can be reduced by 40 % due to changes in the operation and management (no cost measures) and by further 75 % due to energy efficient retrofit that covers both, the
building components and the service systems. Measures have been sorted and combined according to a detailed cost-benefit analysis. As some building parts are being used only for some hours each working day it proved successful to design a heating system that can quickly heat a classroom, but then again also can be set to a lower temperature during the off-time. The combination of renovation measures at the building envelope and the heating system led to synergy effects as the lower heating energy need allowed for a lower capacity of the boiler and a smaller size of the radiators.

The white paint in the classrooms made lighting energy savings of 20 % possible. The daylight controlled electrical lighting in some of the classrooms resulted in lighting energy savings of 60 % and was accepted by the users. However it was not economically feasible. The automatic shading system did also lead to a reduction of the lighting energy. The users however disliked the noise that was created during the move of the system as it caused disturbances in the concentration.

Last but not least: the integration of the users (director, teachers, pupils and caretaker) into the retrofit proved to be useful. The identification with the project was good and the users have been motivated to save energy.
Publication in Danish


Abstract:
Indoor environment in schools and institutions for children.

This report analyses some indoor environment problems and recommends solutions. Indoor environment problems are often caused by changed use of the building, changed teaching methods, changed physical behavior of the pupils inside the building, and inadequate building maintenance. Some simple ways of improving the indoor environment are suggested, starting with the building shape and constructions, materials, ventilation as well as operation and maintenance.

In the coming years many renovations and extensions of school building will be made, and they should be adapted to pedagogical reorganization. This reorganization requires tools to be developed that assess the educational and building environments with requirement specification and quality criteria for schools as a whole and for the individual classrooms as well.

Publication in Italian


Abstract:
The study starts from the characteristics of the National school building stock and address the issues related to refurbishment of schools. Particular attention is focused on the social, educational and sustainable requirements asked to modern schools and the way an efficient design can control the environmental and technological requirements according to the new living standard and educational methods. The study deals with the technological rehabilitation actions, intended as operational instruments able to ensure the suitability of the structures to the new environmental conditions and to the maintenance process. AT the same time, the implementation of the energy performance of school buildings maintaining at the same time the value of the building system, including user-friendliness and conservation issues.

Keywords: Technological refurbishment, energy refurbishment, environments

Free download: http://www.fedoa.unina.it/4125/1/lagioia.pdf
Publication in Norwegian


Abstract:
Article about a survey among persons reported sick caused by asthma. The survey included investigation of accordance between the doctor's judgment and the patient's self-estimated health problems.

Free download: [http://tidsskiftet.no/article/1425904](http://tidsskiftet.no/article/1425904)

Publication in Norwegian


Abstract:
In Norway and many other countries there are an increasing occurrence of asthma and allergy.

Climate change can lead to even additional increase through more pollen spreading. Heritage or gens can no longer be used as a single explanation. Several research results point at environmental factors, both outdoors and indoors. The strategy is a tool to strengthen and coordinate efforts to stop this negative trend.

Publication in Italian


Abstract:
Dynamic simulations were performed on a school reference building. All the energy uses were considered. The study analyses a number of variants in order to define the most efficient refurbishment actions. The variants include: building envelope components, air tightness, solar control of the transparent and opaque components. The numerical analysis is carried for different Italian localities.

Keywords: Energy performance, benchmark indexes

Free download:

Publication in German


Abstract:
This guideline is one of the results of the research project ‘EnEff:Schule’ (Energieeffiziente Schulen - Energy Efficient Schools) sponsored by the German Ministry of Environment and technology. It presents on 20 pages various aspects of the energy efficiency of school buildings, the user behaviour and the impact on the teaching and learning environment. The following topics are raised and possible positive influence factors on them are explained:

- What is an energy-efficient school?
- Actual utilisation time of schools
- Physical background of user comfort
- Control strategies and user acceptance
- Optimisation of the operation of school buildings
- Ventilation needs and strategies
- Room temperature control
- Energy efficient heating systems
- Good lighting conditions
- Integration of energy into the curricula

Keywords: Energy-efficient school, ventilation, operation, lighting, control strategies, curricula


Publication in Italian


Abstract:

The energy audit and diagnosis of public buildings are an important issue for the public authorities, since a more efficient energy management provides significant environmental and financial benefits. This is particularly true for school buildings. Objectives of the study are:

- Assess the actual energy performance of the analysed buildings.
- Define the most efficient energy refurbishment criteria.
- Define a simplified audit methodology to be applied in similar conditions.

More than 50 schools were analysed with the support of pertinently trained operators’ teams. The report presents the implemented methodology and the achieved results.

Keywords: Energy audit, Energy diagnosis

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Publication in Norwegian


Abstract:
The report present post occupancy studies, focused on the dynamics between energy efficient buildings and their users; mainly been on the use, operation, indoor environmental comfort, and the social and cultural context of the buildings. Questions examined are: Which user actions and attitudes may influence building performance and how are the users’ actions and attitudes influenced by the buildings? The report is a delivery from The Research Centre on Zero Emission Buildings (ZEB), Norway.

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Publication in Danish


Abstract:
Conflicting design reasons linked to the light, acoustics and ventilation provides experience problems when creating a healthy climate for the school buildings. An SBI-Direction supervisor therefore decision makers in better overall planning, the design of energy-efficient schools.

Pedagogy is being transformed into the modern school. This requires increased flexibility to the school physical environment. There are also a myriad of solutions for creating an architecture, an interior and an indoor climate that provides a balanced whole with due regard to energy and environmental issues. The difficulty for school leaders, staff and their advisors is to get an overall understanding of the many aspects that are in play in the design of a new school or converting an existing school. The purpose of the SBI-Direction ‘Energy efficient schools’ is therefore to provide a comprehensive description of important topics for creating such a unified picture.

The direction has a special focus on topics which are notoriously problematic and creates unnecessarily high energy consumption. For example, a good use of daylight, this is important for school children’s common welfare and thus learning capacity. At the same time daylight saving electricity for artificial lighting. Supply fresh air is also important for pupils' social abilities. It requires attention to temperature control and a good ventilation system with limited power consumption. To achieve a good learning environment, teachers and students also have decent
acoustics. It can be both complicated by demands from the school premises on multi-functionality and conflicting desires for the rooms' design in relation to light and sound.

The challenges are many when policymakers and their advisers must make choices about the best solution to meet the individual school's needs.

SBi-Direction 212, 'Energy efficient schools', was the final report in DEA's research project “Program for energy efficient schools”. The project is implemented by SBi and DELTA Danish Electronics, Light and Acoustics, in cooperation with Copenhagen Municipality, Ballerup Municipality, Skanska Jensen A/S, Cenergia A/S and Birch & Krogboe A/S.

Publication in Danish


Abstract:
The project has aimed to develop methods and examples related to the design of extensive energy renovations (low energy class 1), thereby stimulating energy conservation and increased use of renewable energy in existing buildings.

There is a large energy saving potential and a need to demonstrate how school buildings from 1960/70’s can be renovated in the form of an energy future security and also to ensure good and healthy indoor climate conditions.

There is therefore good reason to examine how this type of school building can be upgraded to BR08, energy class 2 or 1 level. This report is based on a specific type of school building from the 1970s and the possibilities are examined for a technical and economic extensive energy renovation.

Publication in English


Abstract:
Since the last decades of the 19th century, technological advances have brought substantial improvements in the efficiency with which energy can be exploited to service human needs. That trend has been accompanied by an equally notable increase in energy consumption, which strongly correlates with socioeconomic development. Nonetheless, feasible gains in the efficiency and technology of energy use in towns and cities and in homes have the potential to contribute to the mitigation of greenhouse-gas emissions, and to improve health, for example, through
protection against temperature-related morbidity and mortality, and the alleviation of fuel poverty. A shift towards renewable energy production would also put increasing focus on cleaner energy carriers, especially electricity, but possibly also hydrogen, which would have benefits to urban air quality. In low-income countries, a vital priority remains the dissemination of affordable technology to alleviate the burdens of indoor air pollution and other health effects in individuals obliged to rely on biomass fuels for cooking and heating, as well as the improvement in access to electricity, which would have many benefits to health and wellbeing.

Subscription (free download in some countries): [http://www.thelancet.com/](http://www.thelancet.com/)

Publication in English


Abstract:

Scientific literature on the effects of ventilation on health, comfort, and productivity in non-industrial indoor environments (offices, schools, homes, etc.) has been reviewed by a multidisciplinary group of European scientists, called EUROVEN, with expertise in medicine, epidemiology, toxicology, and engineering. The group reviewed 105 papers published in peer-reviewed scientific journals and judged 30 as conclusive, providing sufficient information on ventilation, health effects, data processing, and reporting, 14 as providing relevant background information on the issue, 43 as relevant but non-informative or inconclusive, and 18 as irrelevant for the issue discussed. Based on the data in papers judged conclusive, the group agreed that ventilation is strongly associated with comfort (perceived air quality) and health [Sick Building Syndrome (SBS) symptoms, inflammation, infections, asthma, allergy, short-term sick leave], and that an association between ventilation and productivity (performance of office work) is indicated. The group also concluded that increasing outdoor air supply rates in non-industrial environments improves perceived air quality; that outdoor air supply rates below 25 l/s per person increase the risk of SBS symptoms, increase short-term sick leave, and decrease productivity among occupants of office buildings; and that ventilation rates above 0.5 air changes per hour (h⁻¹) in homes reduce infestation of house dust mites in Nordic countries. The group concluded additionally that the literature indicates that in buildings with air-conditioning systems there may be an increased risk of SBS symptoms compared with naturally or mechanically ventilated buildings, and that improper maintenance, design, and functioning of air-conditioning systems contributes to increased prevalence of SBS symptoms.

Publication in English

REHVA Guidebook no 6

Abstract:
Indoor climate and productivity in offices. How to integrate productivity in life-cycle cost analysis of building services. Provides quantitative information on the relationship between indoor climate and productivity. Gives specific examples of the use of life-cycle cost analysis data. Discusses 5 case studies in detail.

The quantitative relationships presented in the guidebook can be used to calculate the costs and benefits of running and operating the building, as illustrated by several examples. One of the aims of the examples is to emphasize that the costs of running the building are much lower than the benefits from improved office work obtained by reducing temperatures or improving of indoor air quality. This is further presented in the guidebook by comparing the typical costs of wages, and typical energy and operation costs.

Subscription: http://www.rehva.eu/en/guidebooks
4. INTERNATIONAL PROJECTS – COMPLETED AND ONGOING

EU project, Sixth Framework Programme (FP6)

4.1. BRITA in PuBs – Bringing Retrofit Innovation to Application in Public Buildings

The BRITA in PuBs project, one of 4 original Ecobuildings projects in the 6th Framework Programme of the EU aimed at increasing the market penetration of innovative and effective retrofit solutions to improve energy efficiency and implement renewables, with moderate additional costs. In the first place, this was realised by the exemplary retrofit of 8 demonstration public buildings in the four participating European regions (North, Central, South, East). By choosing public buildings of different types such as colleges, cultural centres, nursery homes, student houses, churches etc. for implementing the measures groups of differing age and social origin could be reached. Public buildings were used as engines to heighten awareness and sensitise society on energy conservation.

Secondly, the research work packages included the socio-economic research such as the identification of real project-planning needs and financing strategies, the assessment of design guidelines, the development of an internet-based knowledge tool on retrofit measures and case studies and a quality control-tool box to secure a good long-term performance of the building and the systems.

The third main pillar of the BRITA in PuBs project was dissemination. This was divided into a minor part, the training of users and maintenance personnel, and a larger section on publishing the research and demonstration work to different target groups. This was done by using local, national and international networks such as Energie Cités, the internet and other media, and arrangement and participation in symposia and conferences.

The 8 demonstration projects were:

- Nursing Home Filderhof Stuttgart, Germany
- Plymouth City College, Plymouth, Great Britain
- Community Centre Borgen, Norway
- Church in Hol, Norway
- Cultural Center Prøvehallen, Copenhagen, Denmark
- Evonymos Library, Athens, Greece
- Guest House of a University "Brewery", Brno, Czech Republic
- Main University Building, Vilnius, Lithuania

For all the buildings the energy-efficient design, construction and 2 years of the operation have been closely followed and documented in reports. The operation
phase included a monitoring of the energy consumption of at least one full year. A life cycle analysis of the projects has been performed and published in a separate report.

The primary energy consumption of the buildings before and after the retrofit were as follows:

<table>
<thead>
<tr>
<th>Primary energy consumption [kWh/m²a]</th>
<th>Filderhof</th>
<th>Borgen</th>
<th>Hol</th>
<th>Prøvehallen</th>
<th>BUT</th>
<th>VGTU</th>
<th>Evonymos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before retrofit</td>
<td>397</td>
<td>280</td>
<td>257</td>
<td>302</td>
<td>515</td>
<td>284</td>
<td>704</td>
</tr>
<tr>
<td>After retrofit foreseen</td>
<td>177</td>
<td>111</td>
<td>184</td>
<td>197</td>
<td>271</td>
<td>183</td>
<td>362</td>
</tr>
<tr>
<td>After retrofit measured</td>
<td>97</td>
<td>102</td>
<td>141</td>
<td>243</td>
<td>257</td>
<td>186</td>
<td>111</td>
</tr>
</tbody>
</table>

Results show that in most cases the observed values are quite close to predicted ones: where they are significantly different (Filderhof and Hol), the predicted Primary Energy were higher than expected. In case of Prøvehallen the difference, as above mentioned, were induced by unforeseen success of the building: the real user profile in this case was substantially different from what defined at the beginning of the project.

Extract of the publishable results

- Proceedings of the common Ecobuildings Symposium, proceedings of the 2nd common Ecobuildings Symposium
- Socio-economic report on barriers and needs
- Overview on financial schemes
- 8 reports on the concept development of the demonstration buildings
- Blackboard information sheets in several languages
- Retrofit design guidelines separately or as part of the handbook on design guidelines
- Quality control toolbox, available on the project website incl. manual of the toolbox
- BRITA in PuBs information tool available on the project website incl. documentation of the information tool
- Final demonstration projects report. Information module for E-learning platforms
- Publishable Final Activity Report
- Ecobuildings Glossy Brochure: Ecobuildings–Answer to an immense challenge. An important step towards sustainable innovation and security of energy supply of the EU.
- Facility training programme and manual
- Architectural students lecture power-point presentations
Further information on the project and all project results are available at www.brita-in-pubs.eu.

The secondary school's facility in Borgen Community Centre was a demonstration building in BRITA in PuBs. Pictures showing the main building before and after retrofit. Most visible features are the new daylight openings on the roof and new façades. The air inlet tower and a heat recovery unit (roof top) can be seen in the picture to the right. Architects for retrofitting: Hus Arkitekter AS. Photo left: B. Matusiak. Photo right: J. Rollan.

EU project, THERMIE

4.2. MEDUCA – Model Educational buildings for energy efficient integrated design

The overall aim of the MEDUCA-project, co-funded by the EU - Directorate XVII for Energy Thermie Programme, has been to demonstrate that energy efficient educational buildings, where the requirements for an attractive and healthy indoor environment are fulfilled, can be designed and built. The aim was to create educational buildings, which stands out as exemplary models of optimised integrated energy efficient design, and serve as the basis for the development of improved standards, for educational buildings in Europe.

By introducing energy efficient, healthy and environment friendly schools we are setting a good example for our students, pupils, teachers, parents, decision makers, engineers, and architects. All educational buildings are built for people to spend time in during the process of learning. Being in an energy efficient and healthy building during the learning process, the students and pupils will also learn about energy efficient and healthy buildings.

The MEDUCA project encompassed eight demonstration projects in seven countries:

- Grong School, Norway - new construction
- Hökegård School, Sweden – refurbishment
- Tånga School, Sweden - refurbishment
- Egebjerg School, Denmark - refurbishment
- Wittorfer School, Germany - refurbishment
• University of Almeria, Spain – refurbishment
• European Public Law Centre, Lavrion, Greece - new construction
• Environmental Education Centre, Bagheria, Italy - new construction

For these 8 projects design studies have been completed, and the projects have been described, monitored and evaluated. The results of these activities have been compiled in a series of 3 thematic reports covering:
• ventilation
• lighting
• control

Besides a summary report describing each project - aimed at decision makers - has been produced. Finally, an educational training kit for school teachers about the teaching of energy efficiency and RE by the use of the technologies employed on the 5 schools has been produced. All material from the project has been included on a CD-ROM, which also holds PowerPoint presentations of the projects, as well as further documentation about and illustrations of the project – plus a scrap book of material produced as part of the dissemination activities of the various projects.

Of the 7 demonstration projects which were built, 2 were new constructions and 5 renovations. The energy consumptions saved by the 7 projects appear from the table below:

<table>
<thead>
<tr>
<th>Project</th>
<th>Saved thermal energy MWh/year</th>
<th>Saved electricity MWh/year</th>
<th>Total saved energy MWh/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Grong, N</td>
<td>20</td>
<td>16</td>
<td>36</td>
</tr>
<tr>
<td>2. Hökegård, S</td>
<td>205</td>
<td>46</td>
<td>251</td>
</tr>
<tr>
<td>3. Tånga, S</td>
<td>205</td>
<td>46</td>
<td>251</td>
</tr>
<tr>
<td>4. Egebjerg, DK</td>
<td>161</td>
<td>24</td>
<td>185</td>
</tr>
<tr>
<td>5. Wittorfer, D</td>
<td>600</td>
<td>27</td>
<td>627</td>
</tr>
<tr>
<td>6. UalM, E</td>
<td>17</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>7. EPLC, Gr</td>
<td>65</td>
<td>55</td>
<td>120</td>
</tr>
<tr>
<td>Total</td>
<td>1273</td>
<td>222</td>
<td>1495</td>
</tr>
</tbody>
</table>

The total savings (heating and electrical) amounts to 453 tons CO₂ per year.

In the seven demonstration projects 19 different innovative energy saving or renewable energy technologies were tested and evaluated.

In each project the municipal administrations, school administrations, architects, engineers and energy consultants have been involved. During the project 10,000 brochures have been printed and distributed.
After completion all the projects have experienced an overwhelming interest from municipalities, architects and engineering companies, that have visited the projects and learned form the experiences gained by the projects. Several newer educational projects in the various countries represented by the MEDUCA project have been designed using the MEDUCA projects as models for the technologies chosen.

The overall budgets for the 7 completed construction projects exceeded 9 M Euro of which 4 M Euro was used especially for energy saving measures. The total support received from the EU THERMIE programme was 1,6 M Euro.

Contact person: Ove Mørck, Cenergia Energy Consultants, Denmark.


Keywords: Energy efficient design, refurbishment, new construction, ventilation, lighting, control.
A new wing for Grong School and Community House was a demonstration building in MEDUCA.

The solar space in the attic (plenary for outlet air) gives 1) sunshine to rooms facing north, 2) provides heating to outlet air and thereby extra driving forces for ventilation, and 3) provides preheating of inlet air via the heat recovery system.

Photo abow: Jo Arve Toresen. Photo left: Glass og Fasade

EU project, programme EAHC

4.3. Health-Based Ventilation Guidelines for Europe (HealthVent)

Objectives: The HealthVent project will develop health-based ventilation guidelines for non-industrial buildings in Europe (offices, homes, schools, nursery, homes and day-care centres). They will reconcile health and energy impacts by protecting people staying in these buildings against risk factors, and at the same time taking into account the need for using energy rationally and the need for more energy efficient buildings.

The objectives of the guidelines are:

1. target on demonstrated adverse health effects of inadequate indoor air quality and provide tangible health benefits for the building occupants and European populations;
2. help avoid investment and energy cost of ventilation systems and rates which are not supported by evidence of health, productivity and welfare benefits; and

3. integrate and optimize with the other EU policies that are relevant for healthy indoor air, namely source control (CPD, REACH), urban ambient air quality management (CAFÉ), energy using product (EuP) and low energy buildings (EPBD).

Start date: 01 July 2010
Supported by: Executive Agency for Health and Consumers (EAHC)
Frame of Support: Health Programme 2008-2013
Partners:
- Technical University of Denmark (DTU)
- Jena University Hospital (UKJ)
- The University of Milan (UMIL)
- National and Kapodistrian University of Athens (NKUA)
- Faculty of Engineering University of Porto (FEUP)
- National Institute of Health and Welfare, Helsinki (THL)
- University of La Rochelle (ULR)
- SINTEF Energy Research, Trondheim (SINTEF)
- Federation of European Heating and Air Conditioning Associations, Brussels (REHVA)
- Association Asthma, Sofia (AA)
- European Federation of Allergy and Asthma Associations, Brussels (EFA)
- COLLABORATORS
- Joint Research Centre, Ispra (JRC)
- World Health Organization, Bonn (WHO)

International Energy Agency (IEA), ECBCS Task 40

4.4. **Task 40: Net zero energy buildings**

Duration: October 2008 – September 2013

Topic:

Given the global challenges related to climate change and resource shortages, much more is required than incremental increases in energy efficiency. Currently, a
prominent vision proposes so called "net zero energy", "zero net energy", "net zero carbon" or "equilibrium" buildings. Although these terms have different meaning and are poorly understood, several IEA countries have adopted this vision as a long-term goal of their building energy policies.

What is missing is a clear definition and international agreement on the measures of building performance that could inform «zero energy» building policies, programs and industry adoption.

Website: [http://www.iea-shc.org/task40/](http://www.iea-shc.org/task40/)

International Energy Agency (IEA)


Operating Agent: Hans Erhorn, Fraunhofer Institute of Building Physics, Nobelstr. 12, D-70569 Stuttgart. Germany.

Email: erh@ibp.fhg.de

Website: [http://www.annex36.com/](http://www.annex36.com/)

Summary:

Educational buildings such as kindergartens, schools, training centres and universities display many similar design, operation and maintenance features in many of the IEA countries. For example, many have similar structures, often need to be retrofitted, and have high energy consumption. Because of the level of similarity that exists within this building sector, experiences gained in developing different approaches to combat similar problems, especially during retrofitting, can easily be transferred to other countries. Two overwhelming similarities amongst these types of buildings are the high energy consumption and necessity to retrofit many buildings within this sector. However, studies have shown that during retrofit energy saving measures are only rarely applied, because of a lack of knowledge by the decision makers regarding the investments and the efficiency of potential energy saving measures. Because of the lack of information, in many cases decisions are made that do not accurately take into account energy saving aspects. There are no "rules of thumb" to enable a quick and easy estimation of the levels of required investment, before an analysis of the building structure in detail. Therefore the development of an 'energy concept adviser' for economical retrofit measures would be useful during the planning and realization phase, on the one hand to help the investor to find the energetically and economically most efficient energy saving measures, and on the other to prevent him from exaggerated expectations. The 'adviser' should be applicable during the entire retrofitting phase to ensure that both the calculated energy savings and the economical success will be achieved after retrofitting. This annex therefore aimed to develop such a tool.

The objectives of this project were:
To develop simple prediction tools for retrofit concepts which allow the decision maker to evaluate integrated construction, installation and lighting measures.

To develop a ‘concept adviser’ to analyse existing buildings and their economic efficiency, and to supplement this by simple methods for testing the efficiency of the applied measures.

To promote energy and cost efficient retrofit measures and to support the decision makers in evaluating the efficiency and acceptance of available concepts.

There were four research areas:

1. Selection and Analysis of Existing Information

In this research area existing information and knowledge in the IEA member countries was collected and analysed. The state-of-the-art knowledge was documented and differences between the countries identified to make evident existing gaps in the knowledge, and to point out appropriate solutions, which were elaborated within the other research areas. The work mainly focused on requirements, guidelines, building types, technologies, benchmarks and decision criteria. Experts from the participating countries collected and prepared extensive information on special topics to be provided for the project participants as knowledge transfer.

Results:

- A report consisting of a catalogue of benchmarks and solutions for different educational building types (technologies, materials etc.)
- A working Document on parameters / design guidelines for good learning and teaching environments
- A working Document on design criteria (e.g. economic analysis, functional requirements)

2. Case Studies

The project case studies included a collection both of exemplary completed and of 8-10 "new", innovatively retrofitted buildings (from the late 90's) of which a few were still under construction and due to be finished in 2000 - 2002. The case studies included schools, institutional and laboratory buildings, with innovative energy saving measures, daylighting and artificial lighting systems with advanced control systems. Measured performance data included temperatures, illuminances and other comfort criteria of the interior space, heating, cooling and electrical lighting consumption, the power consumption of the installations and control systems, the total building energy consumption and the indoor air quality. User acceptance of environmental conditions was assessed through questionnaires. In a design forum, national concepts of planned demonstration projects were reviewed and compared to the experience gained in the other countries.
Results:
- Design Guidelines for retrofitting of educational buildings
- Case Studies Report with documented evidence of energy saving potential of retrofitting processes.

3. Software Development and Analysis Methods
The design tools used included selected tools, ranging from simple spreadsheets to advanced computer programs that took into account the impact of light, heat and cooling in buildings. Work on simple and integrated design tools included validation as well as the improvement of user interface and optimization of calculation procedures. Work on analysis methods focused on short-term measurements and on the comparison of audit procedures and evaluation measures.

Results:
- A working Document on simple calculation tools for decision makers by setting up benchmarks, regulations and spreadsheets
- A report on energy audit procedures including short-term measurements for components and systems (comparison and recommendations)
- A working document including a list of principles and systems to simulate in retrofitting projects and an evaluation of design tools (list and recommendation)
- A working Document on operating procedure including checklist (manual) and evaluation of special measures by means of energy auditing, short-term measurement and questionnaires.

4. Documentation and Dissemination
Documents and dissemination focus on the transfer of the research results to be used by practitioners. Several methods were used for information dissemination. Besides the conventional ways of dissemination, such as newsletters and practice articles, media like the Internet were also used. Apart from publications written in English, publications in the languages of the participating countries were also produced.

Results:
- Website
- Articles
- Newsletters
- Conference papers
Joint Working Group "Energy Concept Adviser"

All the research areas provided their results as input to the joint working group. Based on the results the joint working group developed an electronic interactive source book (The 'Energy Concept Adviser' (ECA)). A central database includes all project results and allows the user to obtain extensive information, according to his/her individual focus of interest, on design inspirations, design advice, decision tools and design tools. Thus, the user is able to increase his knowledge in the respective field of interest quickly and reliably. The user has the choice of analyzing design scenarios himself and/or use the pool of experience gained in the case studies projects to access information on energy saving potentials and requirements.

Results:

- Electronic interactive source book including design inspirations, design advice, decision tools and design tools

Participating Countries: Denmark, Finland, France, Germany, Greece, Italy, Poland, USA, UK

Website: [http://www.annex36.com/](http://www.annex36.com/)
Screenshots of the Energy Concept Adviser tool of IEA ECBCS Annex 36: Start screen (above) and matrix of the more than 30 school retrofit case studies presented in the tool (left).

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International Energy Agency (IEA)


Status: Completed (2005-2009)

Operating Agent: Dr Alexander Zhivov, Energy Branch US Army Corps of Engineers, ERDC - CERL, 2902 Newmark Dr., Champaign, IL 61826-9005, USA.

Email: Alexander.M.Zhivov@erdc.usace.army.mil

Website: http://www.annex46.org, www.annex46.de

Summary:

The scope of the project is the decision making process for energy retrofitting of Government non-residential buildings: e.g., office buildings, hospitals, large one-storey production facilities and maintenance shops and speciality warehouses and school buildings. The project is meant to influence the decision making process that determines the use of energy-saving measures in building retrofits. This decision making process must improve if it is to successfully cope with the challenges of increasing energy costs and climate change, and if it is to avoid “locking in” long-term commitment to energy inefficiencies by adopting sub-optimal renovations. Consequently, the target group consists of all actors involved in this decision making process, specifically executive decision makers and energy managers of Government buildings, performance contractors and designers. The “EnERGo IT-Toolkit”, supplemented by guidelines and best practice examples, will support these different user groups, and facilitate communication between them. The objectives are to:

- provide tools and guidelines for decision makers and energy managers, performance contractors and designers to improve the working environment of Government buildings through energy-efficient retrofitting projects. Though the focus of this Annex is on Government buildings, many results can be applied to similar private sector buildings;
- provide recommendations on how to operate the retrofitted buildings;
- promote energy- and cost-efficient retrofit measures by providing successful examples;
- support decision makers in evaluating the efficiency and acceptance of available concepts;
- find improved ways of using Energy Performance Contracts (ESPC's) for Government buildings retrofit measures.

To accomplish these objectives, participants have carried out research and development in the framework of the following three research areas and one joint working group:

- develop an energy assessment and analysis methodology / protocol and a tool “Energy Assessment Guide for Energy Managers and ESCO's”;
- develop a database of “Energy Saving Technologies and Measures for Government Building Retrofits” with examples of best practices;
- develop “Best Practice Guidelines for Innovative Energy Performance Contracts”;
- develop the “EnERGo IT-Toolkit”.

Participating countries: Canada, Denmark, Finland, France, Germany, Italy, Russia, UK, USA
EU project, Seventh Framework Programme (FP7)

4.7. **Energy Efficiency and Risk Management in Public Buildings (EnRiMa)**

Abstract:
The aim of the project is to develop a decision-support system to enable operators to control energy flows in energy-efficient buildings and areas of public use. This process will be achieved via integrated management of conflicting goals such as minimising costs, improving energy efficiency, meeting emission reduction requirements as well as managing risk.

The project was launched on 1 October 2010 and will run until the end of March 2014.

Website: [http://www.enrima-project.eu](http://www.enrima-project.eu)

EU project, Seventh Framework Programme (FP7)

4.8. **HITEA - Health Effects of Indoor Pollutants: Integrating microbial, toxicological and epidemiological approaches.**

Abstract:
The overall aim of the HITEA study is to identify the role of indoor biological agents in development of long term respiratory, inflammatory and allergic health impacts among children. The focus is on microbial exposures due to dampness problems of buildings; in addition, the role of allergens, chemicals, cleaning agents, traffic exhaust and poor ventilation will be studied. The study includes a cross-sectional and a longitudinal study in school buildings in three European countries.

The project started 1.4.2008 and the planned project duration is five years.

Website: [http://www.hitea.eu/](http://www.hitea.eu/)

EU project under the programme Energy, Environment and Sustainable Development

4.9. **HOPE: Health Optimisation Protocol for Energy-efficient Buildings. Pre-normative and socio-economic research to create healthy and energy efficient buildings**

Abstract:
It becomes clear that there may be a potential conflict between strategies to reduce energy consumption and to create healthy buildings. For example, a particular material/product might have a low embodied energy but cause unhealthy emissions, or the ventilation rate may be reduced to save energy but the level of pollutant concentrations may increase above a certain threshold and increase exposure. While there is a strong logic to improving energy performance by attention to healthy indoor environments, more needs to be done to realise the potential. Action needs to
be directed at both improving guidance on how to realise the potential, and making a convincing case for the building industry to make changes. This project aimed to contribute to both, by providing guidance that is technically sound, while being linked with easily understood examples of good design.

The project lasted from 2002 till 2005.

Website: [http://hope.epfl.ch](http://hope.epfl.ch)

Intelligent Energy Europe Programme (IEE) / CIP

4.10. BUILD UP – Second Buildings Platform to support the implementation of the Energy Performance of Building Directive (EBPD)

The BUILD UP initiative was established by the European Commission in 2009 to support EU Member States in implementing the Energy Performance of Buildings Directive (EPBD).

The BUILD UP web portal is intended to reap the benefits of Europe’s collective intelligence on energy reduction in buildings for all relevant audiences. It will bring together new practitioners and professional associations while motivating them to exchange best working practices and knowledge and to transfer tools and resources.

Website: [http://www.buildup.eu](http://www.buildup.eu)

Intelligent Energy Europe Programme (IEE) / CIP

4.11. EDUCA RUE – Energy Efficiency paths in educational buildings

The project aims at improving energy performance in the building sector at local level and with particular attention to educational building, by promoting the ability of local players to guide and orient initiatives designed to encourage energy saving by means of specific measures and integrated tools. The use of planning and programming tools, as well as reward and support schemes, will be harmonized via a process of cooperation and coordination involving local government players.

End of project: June 2010.

Website: [http://www.educarue.eu/](http://www.educarue.eu/)

Intelligent Energy Europe Programme (IEE) / CIP

4.12. The GreenBuilding Programme (GBP)

GreenBuilding is the European Commission’s Programme to enhance the Energy efficiency in non-residential buildings.

End of program: May 2010.

Website: [http://www.eu-greenbuilding.org/](http://www.eu-greenbuilding.org/)
4.13. **INTEND - Integrated Energy design in public buildings**

Integrated Energy Design (IED) aims to collaborate in the design team (builder, architect, engineer) from the earliest stages of the project. In this phase decisions have the most impact compared to building costs. IED identifies the right design premises and goals from the very start. Passive features like orientation of the building and awareness concerning the use of materials in the construction (e.g. glass, insulation) are important for a good energy design. IED also focuses on the influence each part of the design has on the whole construction. E.g. ventilation strategies will have an effect on the thermal indoor climate, fire conditions and is affected by daylight. Mechanisms to backtrack the decisions made in the design phase are important in IED.

End of project. December 2009

Website: [http://www.intendesign.com/](http://www.intendesign.com/)


The NorthPass project is focusing on new residential buildings. The objectives are: defining very-low energy house criteria and concept adapted to the North European countries; finding solutions to remove the market barriers; remove the gap between demonstration and broad market penetration and support the implementation of the EU's strategy on very low-energy buildings.

Project duration: 2009 - 2012

Website: [http://www.northpass.eu](http://www.northpass.eu)
5. NATIONAL PROGRAMMES AND CENTRES

5.1. The Danish Knowledge Centre for Energy Savings in Buildings

The Danish Knowledge Centre for Energy Savings in Buildings was established in 2008 to increase the uptake of energy efficient renovation measures in buildings. It focuses on the key barrier to action for property owners, namely easy access to a reliable quality installer or, in the case of major renovation, a range of professionals. Consequently, this centre primarily addresses professionals of suppliers of products and services – the so called supply chain. Since 1997 the Danish Energy Performance Certificate (EPC) has been providing detailed information and recommendations about what could be done addressing the building covered by the specific certificate. But for that information to be turned into action the Knowledge Centre has been obliged to provide the supply chain with a set of tried and tested tools and techniques. These tools and techniques and the framework and the channels of dissemination has been developed in conjunction with key actors in the supply chain, such as craftsmen, energy consultants, builders merchants, building material manufactures and building researchers.

The government has allocated 32 million Danish kroner (approximately 4.3 million EURO) for the establishment and operation of the Knowledge Centre from 2008 until 2011. The Centre refers to Centre for Energy Savings under Danish Energy Agency.

A consortium is running the Knowledge Centre for Energy Savings in Buildings, consisting of: Danish Technological Institute, Danish Building Research Institute/Aalborg University, Viegand & Maagøe and KommunikationsKompagniet.

Website: http://www.byggeriogenergi.dk (in Danish).

5.2. ZEB - Danish Research Centre on Zero Energy Buildings

Strategic Research Centre on Zero Energy Buildings was in 2009 established at Aalborg University by a grant from the Danish Council for Strategic Research (DSF), the Programme Commission for Sustainable Energy and Environment, and in cooperation with the Technical University of Denmark, Danish Technological Institute, Danfoss A/S, Velux A/S, Saint Gobain Isover A/S, and The Danish Construction Association, the section of aluminium facades. The centre is led by professor Per Heiselberg, Department of Civil Engineering.

The purpose of the centre is through development of integrated, intelligent technologies for the buildings, which ensure considerable energy conservations and optimal application of renewable energy, to develop zero energy building concepts. In cooperation with the industry, the centre will create the necessary basis for a long-term sustainable development in the building sector.

Based on the rapid progress within material technology, information technology and sensor technology, in an interdisciplinary environment new intelligent building
components and building systems will be developed, that are able to adapt their function and characteristics in proportion to the current need, to the users’ behaviour, and to the renewable energy production, and in that way to eliminate both the need of fossil fuel and fulfil the users’ demands on the function and the indoor environment of the building.

In the development of zero energy building concepts for new and existing buildings emphasis is placed on finding the optimal balance between energy savings and renewable energy production in the building in interaction with energy supply system, so that the total resources are utilised best possible. In this way the centre will contribute considerably to the governments and EU’s energy policy as regards sustainable development, ability to compete and security of supply.

Website: [http://www.en.zeb.aau.dk/](http://www.en.zeb.aau.dk/)

5.3. **InnoBYG – Danish innovation network for energy efficient and sustainable construction**

The innovation network for energy efficient and sustainable construction - InnoBYG - is the new innovation network of the construction industry in Denmark. The Danish Agency for Science, Technology and Innovation has granted a co-financing of 20 million DKK to the new network.

InnoBYG brings the industry together across professional competency. The network has focus on knowledge sharing, networking and development of the industry among its members, both domestically and internationally.

Between 2010 and 2014 InnoBYG will facilitate the development of the construction industry by addressing a number of societal and technical challenges, all of which are related to energy efficiency and sustainability in the construction industry.

5.4. **LavEByg – Danish innovation network on integrated low energy solutions in buildings**

LavEByg is an Innovation Network on Integrated Low Energy Solutions in Buildings and the members are primarily researchers from key knowledge institutions in Denmark and professionals in the building industry.

LavEByg is to ensure that the great potential for energy savings (60-80% over the next 40 years or so) is achieved - both in connection with new buildings and with energy renovation of existing buildings. Through stimulation of research and development of the necessary technologies, the network tries to realize the vision of energy efficient buildings with a good indoor climate, but without the need for fossil fuels.

LavEByg main players are the relevant knowledge institutions in Denmark: The project leader: Department of Civil Engineering, Technical University of Denmark (DTU Byg); International Centre for Indoor Environment and Energy (DTU Byg -
ICIEE); Department of Civil Engineering, Aalborg University (AAU); Danish Building Research Institute (SBI) and Danish Technological Institute.

LavEByg gathers a number of central main players from Danish research environments, major private enterprises (Velux, Danfoss, Rockwool, COWI, Carl Bro, Kuben Byg and others), trade organizations and professional networks (Danish District Heating Association, Danish Construction Association, Elsparefonden and others) and public authorities (Danish Energy Authority, National Agency for Enterprise and Construction).

5.5. The German research project Energy Efficient Schools (EnEff:Schule) Initiated by the German Ministry of Economy and Technology – BMWi-Forschungsvorhaben Energieeffiziente Schulen (EnEff:Schule)

Status: Ongoing (2008 - )

The accompanying scientific analysis of the research project ‘EnEff:Schule’, which is financed by the Germany Ministry of Economy and Technology (BMWi) and is part of the research programme ‘Energy Optimised Buildings (EnOB) aims at bringing together and presenting all activities in the field of energy efficient retrofit of school buildings. Another focus is the scientific analysis of the demonstration projects that are planned, realised and monitored within EnEff:Schule. The demonstration projects show the various innovative possibilities to radically reduce the primary energy demand for space heating, hot water, ventilation, cooling and lighting.

The included demonstration projects will reach different energy efficiency levels due to the retrofits. Besides energy surplus schools that are generating more energy than they use, also 3-liter-house schools take part in the project. Additionally exemplary retrofit projects, so-called best practice examples which are realised outside of the programme, are presented. Those projects have received funding either from BMWi or from other institutions.

What makes school retrofits special is the possibility to incorporate pupils in the retrofit process. This offers the chance for an enormous multiplication of knowledge. An accompanying social-scientific analysis gathers the different ways how to integrate the school retrofit into the curricula. The analysis shall also investigate the impact of the projects on the user behaviour and the attitude of teachers, pupils, caretakers and parents.

Project team: Fraunhofer Institute for Building Physics, University of Applied Science Munich, Fraunhofer Institute for Systems and Innovation Research, Institute for Resource Efficiency and Energy Strategies

Website: [http://www.eneff-schule.de](http://www.eneff-schule.de) (in German, integrated BUILD UP community ‘School of the Future’ in English)
Results/publications:

- Several reports on the design, realisation and evaluation of school retrofits (in German)
- Guideline 'Improved Learning in Energy Efficient Schools' ('Besseres Lernen in energieeffizienten Schulen') (in German, see also publications)

Matrix of the three different energy efficiency levels of retrofitted school buildings within the EnEff:Schule research initiative
- energy surplus schools,
- 3-liter-house schools and
- best practice schools filled with 3 case studies and the used technologies. The complete overview is available at http://www.enEFF-schule.de/. © Fraunhofer IBP.

5.6. The Norwegian centre on Zero Emission Buildings (ZEB)

ZEB is running for a period of 8 years, from 2009 to 2017. The centre is funded 50% by the Research Council of Norway and 50% by the industry. The Norwegian University of Science and Technology, NTNU, and SINTEF lead and coordinate the activities of the centre. Many industries, architectural and consulting offices, professional associations and state institutes are partner of the centre. Seminars and workshops are organized regularly, to reach all the partners, inform them about latest development and receive their feedback. Several pilot ZEB buildings are planned in activities of the centre, and these pilot projects will allow reaching larger audience, both in Norway and internationally, due to the resonance effect of demonstration projects and related publications and dissemination of information.

The work is focused in five areas that interact and influence each other:

- WP1: Advanced materials technologies
- WP2: Climate-adapted low-energy envelope technologies
- WP3: Energy supply systems and services
- WP4: Energy efficient use and operation
- WP5: Concepts and strategies

Website: http://www.sintef.no/projectweb/zeb/
5.7. Gemini – Norwegian centre on energy supply and air conditioning in buildings.
Gemini-senter Energiforsyning og klimatisering av bygninger

Personnel from the research institute SINTEF Energy AS and from the Norwegian University of Science and Technology (NTNU), working with related subjects, have established this centre to ease the cooperation from both a strategically and operationally point of view. Researchers from SINTEF contribute to teaching and learning activities at NTNU, and personnel from NTNU are taking part in SINTEF’s contractual research projects.

Website: http://www.sintef.no/SINTEF-Energi-AS/Gemini-senter-Energiforsyning-og-klimatisering-av-bygninger/

5.8. Reduced energy consumption – impacts on indoor air quality and health (e-CONIIAQ) Schools – Norwegian programme

The project directs much effort towards the school buildings. The economic situation for most school owners causes solutions that hardly meet minimum requirements. Ventilation and thermal conditioning are areas where money can be saved. In the project schools under renovation and school using different HVAC solutions have been subject to investigations. The methods used to evaluate air quality and energy consumption include interviews, on site monitoring, web based questionnaires, supplier information, simulations, monitoring energy, etc. Results will be presented in master thesis, journal and conference papers. The findings so far support the opinion that reduced energy consumption must be met with proper design and qualified operation of the HVAC systems.

Funding: The Research Council of Norway + partners
Project started in 2009, ends in 2013
Web-site: http://www.sintef.no/Projectweb/e-coniaq/

5.9. Reduced energy use in Educational buildings with robust Demand Controlled Ventilation (reDuCeVentilation) – Project funded by the Norwegian Research Council

The project's goals and subtasks:
A number of studies show that demand-controlled ventilation (DCV) reduce energy use for ventilation by 50–60% compared to systems with constant air volume (CAV) for schools with traditional classroom teaching. The use of the schools has changed and the energy saving potential in modern schools must be reanalysed. In addition, advances in sensor technology, communications and control systems involves opportunities for more robust and energy efficient demand-driven systems. A
prerequisite for investing in such systems is satisfactory knowledge of appropriate concepts and corresponding energy savings potential among decision-makers.

This project will develop concepts of robust demand management and dissemination of knowledge about energy saving potential in a teaching and produce computational tools that document the energy savings potential satisfactory in relation to the Norwegian building regulations. The tools will help to improve the design, operation and maintenance and thus reduce the risk of unnecessary energy consumption and operating costs throughout the life of the ventilation system.

The project is focused on educational buildings, but the results will probably be valid for other types of buildings. This will be explored further in the Research Centre on Zero Emission Buildings - ZEB.

Funding: The Research Council of Norway + partners.

Project was started in 2009 and will end in 2012.

Website: http://www.sintef.no/Projectweb/reDuCeVentilation/English-version/

5.10. FutureBuilt – Norwegian programme

FutureBuilt is a ten-year programme (2010-2020) with a vision of developing carbon neutral urban areas and high-quality architecture. The aim is to complete a number of pilot projects – urban areas as well as individual buildings – with the lowest possible greenhouse gas emissions. These prototypes will also contribute to a good city environment with regard to ecological cycles, health and the general impression of the city.

FutureBuilt sets high quality criteria for the prototype projects. The short-term objective is to complete projects with a fifty percent reduction in climate gas emissions from transport, energy use and materials compared to the current standards. The level of ambition will rise in the coming years.

FutureBuilt is a cooperative partnership between authorities and private enterprises aiming to create an arena for innovation, competence building and exchange of experiences.

www.futurebuilt.no

Marienlyst School in Drammen is a pilot building within the FutureBuilt programme. It is the first passive house school in Norway. The building has demand controlled ventilation, heating and lighting, has a very well insulated and airtight envelope, and is connected to a local plant for heating and cooling.

The project has got financial support from Enova, the state energy agency.

http://www.futurebuilt.no/?nid=206284&projectId=202336
5.11. EcoBuild – Norwegian change-over programme for sustainable building

The programme ØkoBygg lasted for five years and was terminated in 2003. Among other pilot buildings five schools were included in the programme. Research and development projects were connected to the schools.

List of publications from the programme:

Kvernhuset School in Fredrikstad is a pilot building within the EcoBuild programme. Focus areas:

- Utilizing daylight, natural driving forces for ventilation, geothermal heat
- Natural purifying treatment of waste water (grey and black) on site
- Utilizing wood and granite from the site as building materials
- Buildings as teaching tools

http://www.arkitektur.no/?nid=91500&lcid=1044&pid0=84639&type=136123&pid2=84682
6. WEBSITES CONCERNING SCHOOL DESIGN (ENGLISH)

6.1. Building Futures
A Royal Institute of British Architects initiative (RIBA).
http://www.buildingfutures.org.uk/

6.2. International Association for People-environment Studies (IAPS)
http://www.iaps-association.org/links.html

6.3. DesignShare
An International Forum for Innovative Schools.
http://www.designshare.com/

6.4. The Lighthouse
Scotland, Glasgow
http://www.lighthouse.org/schools-education/

6.5. IAQ Tools for Schools
USA EPA
http://www.epa.gov/iaq/schools/

6.6. Daylighting and Productivity - CEC PIER
http://www.h-m-g.com/projects/daylighting/projects-PIER.htm
7. ANALYSIS AND SUMMARY OF THE REVIEWED PUBLICATIONS AND PROJECTS

7.1. ENERGY EFFICIENCY AND RELATED CARBON EMISSIONS

Several papers produced by the United Nations Intergovernmental Panel on Climate Change (http://www.ipcc.ch) and others have outlined the science behind climate change predictions, probable impacts, mitigation measures and possible adaptation. The selected publication and projects in this report are focused on key links between climate change and the building sector. Aiming for greenhouse gas reduction will require a mix of government regulation, financial incentives, behavioural change and increased installation of energy saving measures. Main findings are presented in the following chapters.

7.1.1. Policy issues

Discussions on the appropriate energy policy for the future and the growing concerns about climate change focus regularly on the built environment in particular. The recast of the Energy Performance of Buildings Directive (EPBD) prescribes that by the end of 2018, new public buildings must be nearly zero energy buildings, and two years later this requirement will apply to all new buildings. A nearly zero energy building is, according to the EPBD, a building that has a very high energy performance and the very low amount of energy demand is covered to a very significant extent by energy from renewable sources. The EPBD states the objectives and principles, but it is left to Member States to determine the specific requirements, performance levels and ways of implementation. For example; as a part of their local environmental policies, the authorities of Oslo have decided that all new public buildings in the capital city of Norway should be built according to the passive house standard from 2014 onwards.

7.1.2. Building concepts and standards

Throughout Europe there is a large variety of concepts and voluntary standards for highly energy efficient buildings, and even climate neutral buildings. Several countries have established research centres called centre for zero energy buildings or centre for zero emission buildings. One question addressed is how different are the solutions between nearly zero CO₂ and nearly zero (primary) energy solutions. Work is going on to make consistent definitions, searching for indicators that can properly reflect both energy and CO₂ reductions. The reduced energy consumption reflects, in general, the depletion of fossil fuels and is in many cases considered as sufficiently proportional to CO₂ emissions. However, proportions are distorted when electricity involved is generated by nuclear or biofuel. Nevertheless, in the report «Principles for nearly Zero-energy Buildings» [Boermans et al] it is suggested that if
a single indicator is to be adopted, the energy performance of the building should be indicated in terms of primary energy, as in line with current EPBD. However, to reflect the climate relevance of a building’s operation, CO$_2$ emissions should be added as supplementary information. It should be noted that there are additional requirements for ensuring a match between nearly zero energy buildings and climate targets.

7.1.3. **Conversion factors**

In several projects work is going on to define conversion factors from final to primary energy, based on reality, adapted to the real situation of the energy system. Conversion factors are also influenced by political considerations, which sometimes bring along intense discussions.

In Norway, for example, 70% of the heating demand in buildings is covered by electricity. The Norwegian electricity production is based on hydropower and is perceived to be clean, which may lead to the idea that we don’t have to reduce the consumption of electricity in order to reduce the CO$_2$ emissions. However, if the demand for energy in buildings decrease and thermal energy replace high grade electric energy, where possible, the released power can be used in the transport sector, and that will certainly reduce CO$_2$ emissions. A web-based tool that makes it possible to calculate the greenhouse gas emissions associated to buildings is in the process of being developed ([www.klimagassregnskap.no](http://www.klimagassregnskap.no)) [Statsbygg]. The tool has so far been used in few projects, but will be used in all the pilot building projects of the program FutureBuilt ([www.futurebuilt.no](http://www.futurebuilt.no)).

7.2. **INDOOR CLIMATE AND PUPILS’ PERFORMANCE**

For investigations about the influence of indoor climate on humans’ performance most times there are done field tests (in real buildings) or climate chamber tests (in artificial test rooms), where real persons are exposed to specific indoor climate conditions. The indicators to estimate the influence of indoor environmental quality on performance are very different in these studies, like neurobehavioral tests [Lan et al], an alertness-stress test [Ribic], work speed and errors in writing and math tests as usual school tasks [Wargocki et al] or the standard test scores reached during the school year [Haverinen-Shaugnessy et al]. Therefore it is difficult to compare the results from the different studies directly and to deduce the extent of improvement clearly from the investigation. The second point which should be considered, looking on the results, is that different levels for indoor air quality are used, like different temperature levels or carbon dioxide ranges, for the comparison of a good and a bad indoor air quality. Therefore, in most cases only a trend can be summarized from the studies, but no distinct values.
7.2.1. Influence of Ventilation Rates

The studies investigating ventilation rates [Haverinen-Shaugnessy et al, Ribic, Wargocki et al] show, at least in some of the investigated tasks, an obvious tendency for a better performance of the pupils having high ventilation rates, although all of them use different comparison levels for good and bad air quality. [Franchimon et al] deduced estimation out of a literature review over a broad range of ventilation rates and state that with ventilation rates below 4 l/s/person or 14 m³/h/person performance of pupils sinks considerably, whereas the performance improvement with ventilation rates above 10 l/s/person or 36 m³/h/person is neglectable.

Some studies also investigated the influence of indoor air quality on health either by analysis of bacterial markers [Fox et al] or the amount of appearing chronic diseases [Franchimon et al]. It was shown in these studies that higher ventilation rates result in lower levels of bacteria in the indoor air and in less chronic diseases among the room occupants. This is also confirmed by a literature review [Daisey et al] of over 300 articles. Moreover [Franchimon et al] state that the ventilation rate should not only be adjusted to odours and performance, but mainly to health risks. This estimation is also confirmed by a literature review by [Mendell et al]. They found out that the lower attendance and performance of pupils in rooms with lower ventilation rates mainly accrue from health effects due to a higher level of indoor pollutants.

7.2.2. Influence of Indoor Temperature

Recent studies regarding the influence of indoor temperature on performance investigate the effects of very high temperatures and partly also interactions with the influence of other indoor parameters. The investigations show a positive effect of lowering temperature on performance [Balazova et al], error rates [Witterseh et al] and fatigue [Kawamura et al], sick-building-syndrom symptoms and the perceived air quality [Lan et al]. A direct connection between a low thermal comfort and a low performance [Lan et al, Balazova et al] is seen as well. But it is unclear if there is a direct effect of the temperature on performance or if the reason for poor performance is that with lower thermal comfort the occupants are less willing to exert the effort for a good performance. Nevertheless, due to the connection between thermal comfort and performance, overcooling of the rooms should also be avoided. [Corgnati et al] showed that people prefer conditions, which are voted as “slightly warm” and are already unsatisfied with conditions voted as “slightly cold”. In addition, one study [Balazova et al] also shows that the extent of the effect of higher temperature on performance is overestimated by the occupants.

7.2.3. Influence of noise and acoustics

The studies show that a higher noise level decreases performance in some cases and causes more difficulties in concentrating and fatigue [Witterseh et al, Balazova et al and Kawamura et al]. The effect on self-estimated performance is stated different in the articles from no effect [Witterseh et al] to a very high effect [Balazova
et al]. Bad room acoustic is stated to have a negative effect on the perceived noise level and overall comfort and also on performance [Leistner et al, Kawamura et al], especially when the task is depending on speech intelligibility [Leistner et al].

7.2.4. Influence of illuminance and daylight

There are two investigations [Hoda et al, Kawamura et al] which indicate a higher work performance with increased illuminance of the work space (750 or 1200 lux compared to 400 lux) although the increased illuminance had no effect on fatigue or other physical reactions. Despite of that [Hoda et al] shows that high air velocity or low humidity have a significant negative effect on eye dryness and visual fatigue. [Heschong et al] prove lower performance of pupils in rooms with problems of glare (no blinds or windows to east) and a higher performance in rooms with a good view to outside, esp. to vegetation. They also found a negative correlation between daylight level and performance. But the real reason for this effect was a higher noise level and worse acoustics in these rooms on account of a higher frequency of opening windows.

7.2.5. Comparison of the indoor climate parameters

Noise and indoor temperature seem to have the greatest impact on the perception of indoor environmental quality. When persons are asked for improvement of indoor quality they give priority to temperature and noise rather than lighting [Kawamura et al]. With high temperature their self-estimated performance is falling [Witterseh et al and Balazova et al] and there are more complaints about fatigue [Kawamura et al]. With a higher noise level there are different results of effects on the self-estimated performance. Whereas [Witterseh et al] (compared 35 and 55 dB(A)) could find no effect, [Kawamura et al] (compared with and without traffic noise) recognized an effect and [Balazova et al] (compared 52 and 60 dB(A)) recognized the greatest effect on self-estimated performance with higher noise levels.

Low indoor air quality is accepted more easily by the occupants and illuminance seems to have no effect on the self-estimated perception over a level of 400 lux [Balazova et al].

In contradiction to the self-estimated performance, the objective effect on performance is measurable with improvement of several indoor parameters, especially when more than one parameter is improved at the same time [Balazova et al]. In nearly all the studies, the effect of worse indoor parameters on self-estimated performance didn’t fit to the objective measured performance.

7.3. ENERGY EFFICIENCY AND INDOOR ENVIRONMENT

Airtight buildings, reduced ventilation rates, thick insulation and advanced control systems certainly reduce energy consumption. However, if not properly operated and
maintained they may be risk factors causing indoor air complaints, illness and reduced productivity. Guidance is needed on how to choose the best building materials, to design and use ventilation systems, and establish control routines for securing proper operation [Wargocki and Seppänen et al].

Experience has shown that energy saving measures may affect building constructions and indoor climate, resulting in impaired health and lower productivity. Possible impacts on health and productivity span from almost unnoticeable subjective annoyance to complete work disability [Bakke].

Building methods and construction materials differ between countries. Experienced problems in one geographic region may not be relevant for other regions. It is therefore necessary to generate knowledge and solutions that is adapted to local climate conditions and building habits.

So far, limited practical experience is gained about indoor air quality in low energy buildings and passive houses. There is evidence that indicates health benefits from improved energy efficiency, e.g. in home environments [Wilkinson].

The HOPE project funded by the European Community has addressed the subject reduced energy consumption and healthy buildings. It is concluded that the apparent conflict between health and comfort on the one hand and energy use on the other hand need not, in fact, exist [HOPE].

The NorthPass project funded by the EU programme Intelligent Energy Europe has addressed the subject of indoor climate associated with very low energy houses [NorthPass].

### 7.3.1. Thermal indoor climate

Thermal conditions relate to the temperature, surface temperature, air velocity, air humidity and activity and clothing of the persons in the room.

One of the main reasons that the very low energy building consumes less energy than a standard building is the high level of insulation and airtightness in the constructions. These two factors have great impact on thermal indoor climate and comfort of the occupants. In very low energy buildings walls, floors, ceilings and windows will be homogeneously warm since the constructions are well insulated and airtight and low U-value windows are used.

For a building to be classified as a very low energy building the envelope must, in addition to be very airtight and highly insulated, have minimal thermal bridges to avoid moist and cold from penetrating through the constructions and into the building. Low energy buildings have the benefit of avoiding draft along the floor or downdraft from windows [NorthPass].
7.3.2. **Atmospheric indoor climate**

Indoor air quality is connected to air pollution from people, furniture, surface materials in the room (paint, carpet etc.), and dust, moist, mould etc. in combination with cleaning quality and ventilation rates.

Ventilation rates are set both to provide healthy environments for occupants, and to protect buildings from damage caused by damp. Reduced indoor air quality may significantly affect work performance and productivity [Wyon]. REHVA Guidebook no. 6 states that a minor 1 % increase in office work efficiency can off-set the annual costs of ventilating the building [Wargocki and Sundell et al.]. Reduced ventilation rates may give a significant contribution to energy saving. However, the possibility depends on a number of parameters like: heating and cooling demands, outdoor air quality, air filtration and distribution systems, material emissions, processes and activities. Demand controlled ventilation (DCV) is a mean of saving energy. A challenge is how to make sure that the economical benefit by reducing the ventilation rates not will be outweighed by impaired health and reduced productivity.

Increasing frequency of allergic reactions is partly caused by indoor climate. In such cases very low concentrations of triggering factors are needed. In a study [Leira] 26 % of women and 10 % of men having work-related asthma, stated indoor air climate to be the main reason. Women may seem to be more vulnerable to poor indoor air climate and report work-related indoor air complaints more frequently than men.

Building related asthma and allergic reactions, especially among children, is of concern to the health authorities. For example; a Norwegian ministry focuses in an action plan on housing qualities especially for children, immigrant population and students [Norwegian Ministry of Health and Care Services].

7.3.3. **Acoustic indoor climate**

Acoustic is concerning sound and noise impact such as sound level, reverberation time, whistling from ventilation system, and external noise transmitted through the constructions. Acoustic is related to everything one can hear in the building – internal and external sounds.

Regarding protection from outdoor noise, a very low energy building will generally be better than a standard building because it is much more insulated. Better building envelope gives better reduction of noise from outside. Sounds from traffic and other noisy outdoor parameters can be significantly reduced due to very good insulation and airtightness.

The internal sound parameters have no relation to whether or not one stays in a very low energy building. Materials, furniture and installations in the building set the standard, which is also the case for standard buildings [NorthPass].
7.3.4. Lighting conditions

In general, regarding electrical lighting, it can be claimed that there should be a difference between very low energy buildings and standard ones. Very low energy buildings should also have low energy lighting, e.g. high quality lighting fixtures (reflection-intensifying specular louvre lights) in connection with high efficient lamps (e.g. T5 tubular flourescent lamps) or for example LED-downlights, energy saving ballasts (electronic) or different control systems for adaption to the necessary lighting level by dimming. Dimming optimizes the daylight use and reduces the electricity consumption. Most LEDs have currently still problems to produce the light colour that is good/normal for reading. However the industry developments are improving, and in the near future this problem is expected to be solved.

Concerning very low energy buildings the following aspects might contribute negatively with respect to daylight utilization:

- Better window U-value means lower light transmission of the glazing
- Thicker walls (more thermal insulation) means poorer penetration of daylight

The challenge is to develop solutions for daylighting and solar shading that reduce energy consumption for lighting and cooling and still provide a high quality indoor environment [Arnesen].

White or light coloured interior walls reduce the demand for lighting [Kienzlen et al].