Ali Sayigh *Editor*

Mediterranean Green Buildings & Renewable Energy

Selected Papers from the World Renewable Energy Network's Med Green Forum

Springer

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This book highlights scientific achievements in the key areas of sustainable electricity generation and green building technologies, as presented in the vital bi-annual World Renewable Energy Network's Med Green Forum. Renewable energy applications in power generation and sustainable development have particular importance in the Mediterranean region, with its rich natural resources and conducive climate, making it a perfect showcase to illustrate the viability of using renewable energy to satisfy all energy needs. The papers included in this work describe enabling policies and offer pathways to further develop a broad range of renewable energy technologies and applications in all sectors – for electricity production, heating and cooling, agricultural applications, water desalination, industrial applications and for the transport sector.

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Abstract

This chapter is the result of a European research project developed by the University of Florence – Centro ABITA on adopting energy-saving strategies to reduce the annual energy demand in new and retrofitted hospital buildings. The research project, which is funded by the European Union, aims to apply energy-saving strategies, advanced technologies and plant solutions in five case studies in different climatic areas of Europe: Meyer Children's Hospital in Italy, Fachkrankenhaus Nordfriesland Hospital in Germany, Torun City Hospital in Poland, Deventer Hospital in the Netherlands, and Aabenraa Hospital in Denmark. The research aims to demonstrate the significant opportunity to reduce energy demand in the European hospital sector, thereby contributing to a substantial reduction in CO_2 emissions. The main goal is the integration of strategies for energy efficiency in the hospital sector, in compliance with current regulations, improving environmental quality and ecosystems and promoting sustainable management of natural resources. Innovative strategies for the integration of renewable energies in buildings are combined with bioclimatic design to improve building control and management, upgrading energy efficiency, thermal control and comfort, natural ventilation, and daylighting. Moreover, the use of photovoltaic modules, high-efficiency heat pumps, integration with surrounding green areas, and the use of vegetation inside buildings are explored as opportunities to both reduce energy demand and improve patient comfort. At the end of the project, the researchers provide an overview of the results achieved on indoor comfort, energy savings, and CO_2 not emitted through the energy solutions adopted.

Keywords

Energy Environment Daylighting Energy savings Renewable energies
Natural ventilation Green roof
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Notes

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In the Meyer Children's Hospital project, under a TESIS/ABITA experimental research prog ram, the European Community financed the incremental cost of the innovative technological and environmental solutions that were implemented in the project, monitoring the effectiveness of the results retrospectively. In particular, the experiments involved a bioclimatic greenhouse, a PV system integrated into the translucent wall of the greenhouse, solar tube systems to capture and transfer sunlight to functional environments so as to reduce electricity consumption, innovative solutions of a green roof, and the environmental insertion of the complex into the landscape.

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Energy savings solutions for five Hospitals in Europe

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Keywords: energy, environment, daylighting, energy savings, renewable energies, natural ventilation, green roof

ABSTRACT

This work is the result of a European research project developed by the University of Florence - Centro ABITA, adopting energy savings strategies to reduce the annual energy demand in new and retrofitted Hospital buildings. The research project, EU founded, aim to apply energy savings strategies, advanced technologies and plant solutions in five case studies in different climatic areas of Europe: Meyer Children hospital in Italy, Fachkrankenhaus Nordfriesland hospital in Germany, City Hospital Torun in Poland, Deventer Hospital in the Netherland and Aabenraa Hospital in Denmark. The research aims to demonstrate substantial opportunity to reduce energy demand in the European hospital sector, thus contributing to a significant reduction of CO_2 emissions. The main goal is the integration of strategies for energy efficiency in the hospital sector, in compliance with current regulations, improving environmental quality and ecosystem and promoting sustainable management of natural resources. Innovative strategies for the integration of renewable energies in buildings have been combined with bioclimatic design to improve building control and management, upgrading energy efficiency, thermal control and comfort, natural ventilation and daylighting. Moreover, use of photovoltaic modules, high efficiency heat pumps, integration with the surrounding green areas and use of vegetation inside the building, are developed as opportunity to both reduce energy demand and improve patient comfort.
At the end of the project, the research group provides an overview of the results achieved on indoor comfort, energy saving and CO_2 not emitted through the energy solutions adopted.

Introduction

Hospitals are energy and resource-intensive buildings that contribute to climate change and to respiratory and other illnesses. The properly adoption of energy saving strategies in the health sector can demonstrate a good response to climate change, playing a good role and support healthy and sustainable future.
The implementation of sustainable energy systems is one of the principal objectives of the European Union's energy policy, in order to promote secure energy supplies with high quality services and high environmental comfort. Moreover, Europe intends to build Zero Energy buildings in the next future and the experience made in Hospital sector can be very useful to reach these goals.
The research demonstrate that technological and plant strategies plus renewable energy technologies may be used with very positive results in the European health care building sector and in this way mainly encourage the exploitation of integration of renewable energies.
This paper aims to illustrate the reduction of energy consumption, the comfort achieved from the adoption of energy savings and bioclimatic design solutions, as well as the resulting reduction in CO_2 emissions quantified in the five case studies analyzed.

Objective

Energy efficiency reduces hospital energy consumption and costs. Green building design hospitals are responsive to local climate conditions and optimized to reduce energy and resource demands. Alternative energy generation produce and/or consume clean, renewable energy onsite to ensure reliable and resilient operation. Transportation use alternative hospital vehicles (such as electric); encourage walking and cycling mobility; promote staff, patient and community use of public transport; hospital route optimization to

minimize the need for staff and patient transportation. Reduce, re-use, recycle, compost and use alternatives to waste incineration and conserve water.
Standard operating procedure for most hospitals requires significant energy use, such as for heating water, temperature and humidity controls for indoor air, lighting, ventilation and numerous clinical processes – with associated significant greenhouse gas emissions. Hospitals can implement many measures to improve energy efficiency while satisfying the energy requirements of these important energy-consuming end-uses.
Using combined heat and power (CHP) technology, for example, facilities can generate onsite electricity and capture waste heat from the generation process as thermal energy. This can double energy efficiency by eliminating losses associated with the grid delivery of electricity. For artificial lighting the (LED) light bulbs use can reduce energy consumptions. Two principal objectives adopted in the case studies are:
- conservation, reduction and control of solar radiation;
- provision of natural ventilation and natural cooling of the external building surfaces by evaporative cooling.

Methodology

The adopted bioclimatic and technological Design approach covers a range of strategies to save energy in buildings. Following some strategies adopted coherently with the local climatic conditions and with the specific patient requirements to be achieved:

- Building orientation and form
- Green building design
- Building envelope and materials: Glazing and Double Skin Façade
- Envelope insulation
- Integration of Renewable Energies Photovoltaic (PV)
- Green Roofs
- Rational use of Water
- Daylight Strategies
- Appropriate Shading devises
- Innovative bore holes.

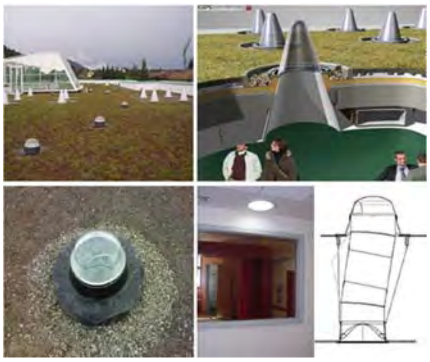
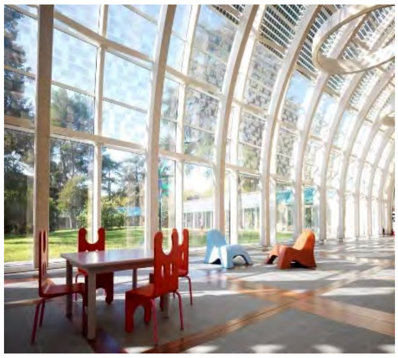
Following the five case studies with specific applied strategies.

Italy: Meyer Children's Hospital, Florence. The designed hospital creates a healing environment for patients and landscape as well. The hospital has a lot open spaces airy and bright with high ceilings, which creates a comfortable place and peaceful setting for little patients and their families. The hospital is well integrated in the surrounding environment with a greenhouse, landscaped roofs, skylights, open "buffer" space, and an energy-efficient hybrid ventilation system. To monitor and conserve energy, the hospital design also includes a "building energy management system" and light tubes that create natural light throughout the building. The hospital consumes 40% less energy for heating and cooling and electricity, than a standard newly-built Italian hospital.

Fig.1 Aerial view of the green roof of the Meyer children hospital Fig. 2 South façade of the new part of the building

Technical solutions

Envelope Insulation: external facades and roofs have an adequate U-value (0.32 W/m2K for external walls and 0.26 W/m2K for the Roof), sufficiently low to reduce as better as possible energy losses; they also have an adequate thermal mass (thermal lag is about 10 hours) to reduce the summer overheating on exposed surfaces (South, West and East exposition).




Figures 3 North corridors and greenhouse Figures 4 Solar pipes and skylights Figure 5 PV facade

Windows and shading - The windows are constructed with wooden frames. Patient rooms are protected from direct sunlight by an overhanging structure externally covered with copper-plates, to reduce the visual impact of the building in the park, with the internal surface covered in wood. The greenhouse is shaded by internal white blinds which are adjusted by an automatic control system.
Sun pipes and light ducts: In order to improve patients' well being, an important aspect is to provide daylight and positive surroundings, with plenty of daylight and high thermal comfort levels. Sun pipes are installed to achieve a good illuminance value in patient rooms. Each room is for two patients and has two windows, one looks outside (surroundings) and has daylight, the other one is illuminated by sun pipes. Solar-tubes and roof-lights in corridors and halls give a good level of daylight
Heating - Heat pumps are used to generate heating and cooling. These are appropriate where both summer cooling and winter heating are required.Radiant panels and high efficiency boilers are used for the heating system.Radiant floor heating panels are installed in patient rooms in which we reach a good level of thermal comfort with a low energy cost.For winter heating and DHW generation there are two boilers: they are condensing combi boilers with an efficiency of about 106 %. The boilers use gas and not electricity.
There is another conventional type boiler which will function only when necessary.
Cooling - For summer cooling there are two electrical chillers. A third chiller is of the water/water type: the heat generated from this last machine is used for DHW.
Ventilation - Ventilation is guaranteed by windows which move up and down: their opening is manual.
A combination of shading and ventilation systems can keep indoor temperature to within 10 °C under outside temperature. To save on cooling energy, passive cooling and ventilation techniques are used as much as possible with air-conditioning only where necessary. Glazing adopted for the Greenhouse has a very low U-value, 0.78 W/m2K . This type of glazing reduces transmission losses and the "greenhouse" effect.
Photovoltaic - The Meyer's photovoltaic greenhouse is a structure with a southern exposition and unobstructed solar access to the main solar glazing of the greenhouse in order to maximize the collection of winter sunshine; it is not only a particular type of structure but also, and more importantly, a particular kind of space. The design objective not only considered energy and environmental aspects but also social impact: the primary objective is to create a pleasant and "socializing" space which can be used for semi-outdoor activities through most of the year without any extra energy space, a social space well integrated into the adjacent green park. The Photovoltaic system is 30 kWp and realised with glass/glass PV modules.
Co-Generation - The design of the co-generation plant is formed by a gas turbine, with an electrical power of 7,5 MWe (ISO), which allows the use of self-produced energy in the hospital complex.
Energy performance - The performance criteria was to achieve a 40% reduction in consumed energy. Results of energy consumption are collected in this section and are derived from simulation, calculation and monitoring. Specific energy consumption targets were: Lighting Sun-pipes and roof-light in corridors and halls provide a good level of daylight. Furthermore all installed lamps are high efficiency.
The total annual electricity demand is 12.3 kWh/m². Compared with the energy demand in which all these features are not applied, the energy saving is 35%. Heating and cooling: Internal temperature and relative humidity measured during the monitoring phase are in accordance with simulations. The insulation used in walls and roof gives an energy saving of 35% for heating and cooling. The annual heating demand is 73.4 kWh/m². The annual cooling demand is 87.3 kWh/m². Domestic hot water (DHW) During the summer period, two chiller machines are used for cooling the hospital. The heat produced is used for DHW. The

annual heating for DHW demand is 13% less than in a conventional Italian hospital. Co-generation plant It was not considered for energy performance because it must be completed.
Project by: CSPE Architects, ABITA Unifi for technological strategies and renewable energies strategies.

Fachkrankenhaus Nordfriesland Phichiastric Hospital, Germany
The hospital is located near the North Sea and it is specialized in psychiatry and psychosomatic disorders.
Achieving superior indoor air quality is a priority in this psychiatric hospital. The designers' emphasis on healthy, low-emitting materials was a response to the hospital administration's belief that indoor air quality improvements would markedly improve the treatment of patients with environmentally related illnesses.
The innovative strategies adopted mainly in order to improve comfort, daylight conditions and indoor climate for the users of the buildings and secondarily to reduce energy consumption and CO_2 emission. A river and rain water capture techniques, a solar mass wall with transparent insulation, a double skin façade, and emissions reduction are key performance indicators. Innovative and natural sources are used in order to minimize metal in the living rooms. Moreover, by improving the daylight conditions, the need of electricity in the living rooms is consequently reduced, and by implementing the transparent insulation on the outer wall, the feeling of comfort inside the building rise. In parallel the energy consumption is reduced. Moreover, environmentally sensitive patients receive 100% organic foods. Special attention is given to windows, treated as multi-functional building components with respect to all the different parameters influencing the indoor climate and energy consumption with a double skin facades.
Double skin facades with integrated natural ventilation and passive cooling is realized into the glass facades facing east and west. The system is created to be used differently according to time of the year and the weather. During summer the glass can reject solar radiation together with a system of lamellas shade the sun. During winter the system is closed and thereby keeps hot air inside the buildings. By implementing the double skin facades the daylight conditions are improved and the use of electricity reduced.

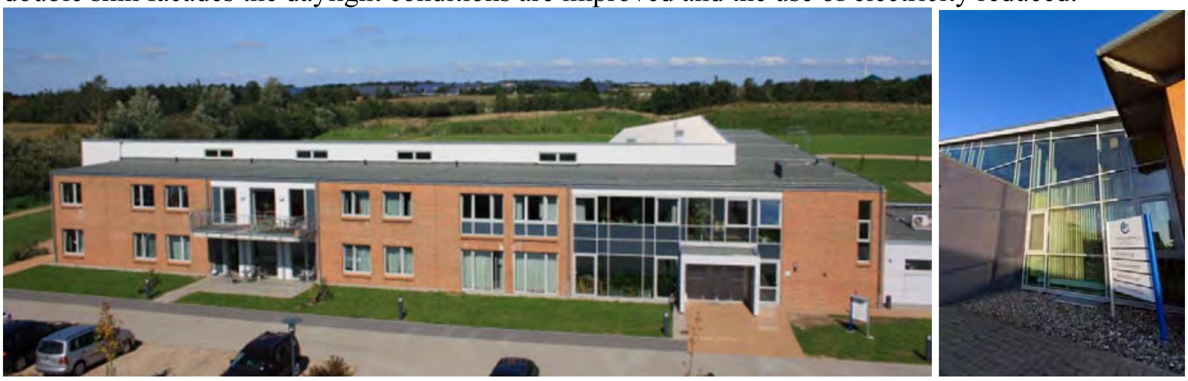


Figure 7 Main entrance in Fachkrankenhaus Nordfriesland Hospital

The hospital's renovation is inspired primarily by energy conservation concerns, innovation in materials selection and careful attention to ventilation.
Energy Description: emission reductions are: CO_2: = 261 740 kg CO2/year, SOx: = 230 kg SOx/year, NOx: = 2 kg NOx/year
Project by: Architect S&I arkitekter A/S

Deventer Hospital, Overijssel, The Netherlands
380-bed hospital with specialty clinics for psychiatry and radiation therapy. The energy savings in the new hospital are 47% on heating and 13% on electricity compared to a standard hospital. This reduction of energy equals the reduction of 1299 ton CO_2 per year, as well as an important reduction in related emissions, e.g. SOx, NOx. The project design focuses on energy efficiency, with energy efficiency measures that results in annual emissions reductions of 1.943 tons of CO_2, 8.71tons of SOx, and 3.35tons NOx. This is a reduction of 69% from the average Dutch hospital. Patient comfort is guarantee with the locating of single, double-, and triple- patient rooms away from public waiting rooms and high-traffic circulation areas; and improving patient access to daylight and views.
The roofs are partly covered with vegetation. Window frames are made of hard wood. Heat- and cold storage is applied using a heat pump and concrete core activation for low temperature heating. The heat is also recovered from the ventilation air. Outside the rain water is transported more slowly to the open surface water using cascades. The integral design has an energy-performance-coefficient of 0,67. The environment-

index of the building, according to the Greencalc method, comes to a score of 212. In the main part of the building the 'hard' facilities are located. At the ground floor are the less flexible policlinics, at the 1st floor the perinatology center, ICU, OR, and daycare, at the 2nd floor the patient rooms, and at the 3rd floor laboratories and pharmacy.

Figure 8 Deventer Hospital building entrance and pond Figure 9 Internal view

The three energy principals of the hospital are:
1. good insulation and natural ventilation.
2. heat recovery techniques like energy wheels, which recovers the heat, cold, and latent energy.
3. alternative renewable energy sources, heat-cool storage and heat pumps and heat recovery application in exhaust ventilation.

The ground is surrounded by a village and a nature reservoir, so ground water level fluctuations are not allowed. Since the conventional techniques could not be used in Deventer for heat-cool storage, a revolutionary new energy concept was designed with better performance, lower costs, higher flexibility and by implementing sufficient redundancy the failure risks are also minimized, which is important for the exploitation budget of a hospital. For this technique, 95% of the effects will occur on the projects ground. Besides, the effects on the environment are positive instead of negative. For a dry winter they send only based on the heat requirements of the building, whereas for a wet winter they send also based on the requirements in the environment, such that the ground water level doesn't fluctuate too much.

Aabenraa Hospital, Denmark

The renovation part includes covering three courtyards with glass and a well-insulated opaque roof, changing the courtyards from outdoor areas to real indoor areas. For the Aabenra Hospital, optimization of the use of day-lighting has been given special attention, since optimum day-lighting conditions had to be provided not only in the glazed courtyards themselves but also in the rooms surrounding the glazed courtyards. For the hybrid ventilation - natural fan assisted ventilation - careful planning of the system controls was necessary in order to ensure that the patients would have optimum thermal comfort during summer, when the risk of overheating has been determined, and in winter, when the cold outdoor air needs preheating in order to provide draft-free fresh air to the building.

Figure 10 Aabenraa Hospital aerial view Figure 11 Internal view

The ventilation system in the glazed courtyards is designed as a displacement ventilation system. Fresh air is provided through external fresh air inlets and passed through the basement, assuring a constant air temperature around 16°C. Fresh air then passes a filter and a convector element. Exhaust is ensured via roof-integrated wind cowls, utilizing the wind load to create sufficient under-pressure in the glass-covered courtyard to ensure the required air change of approximately 1.0 to 1.5 h-1. The roof integrated wind cowls are equipped with assisting fans, to ensure a satisfactory ventilation level when the wind load is not sufficient. The hybrid ventilation system is controlled with a new Building Management System, BMS, including the necessary control points. For each building section, the BMS system controls a number of throttle motors, valve motors, sensors for fresh air temperature, and combined room air temperature and CO2 sensors. All sensors are placed 1.6 m above floor level. District heating is used for space heating and hot water. The generation of hot water is supported by total 150 m2 thermal solar collector area, which provides an annual yield of about 540 kWh/(m²a), covering about 60% of the annual need for DHW.

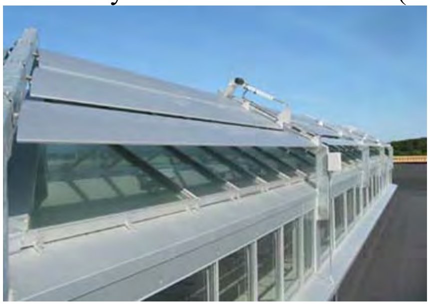
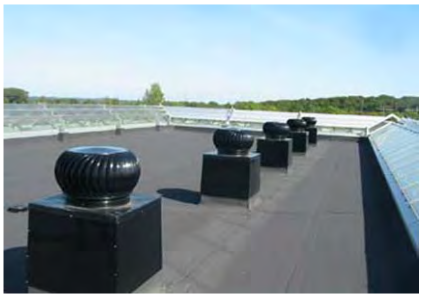
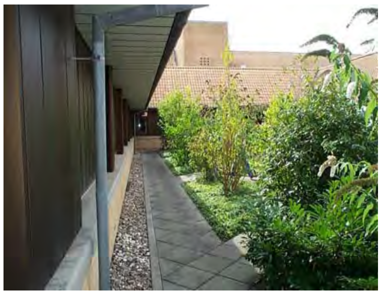




Figure 12 skylight Figure 13 ventilation chimneys Figure 14 courtward

City Hospital Torun, Poland

The Polish city of Torun is a member of WHO's "Healthy Cities" project, so when the city hospital needed renovation and expansion, authorities included environmental sustainability criteria in the plans. Both new and renovated buildings in this 249-bed hospital have upgraded insulation, room temperature controls, modern heaters, and advanced valves, among other measures. Energy savings are approximately 30% in the renovated buildings, and new buildings use 54% less energy than standard newly-built hospitals.
In the Torun hospital, district heating from a CHP is used for space heating and hot water. A cooling system is not necessary, because the hospital is located in a cool climatic zone.
A natural ventilation system is used. The fresh air enters the room through gaps at the top of the windows in the frame. The warm air is brought outwards via a central duct system.


Figure 15, 16 Torun Hospital 100 mm exterior insulation

Results

In the following table are summarized the results achieved for the indoor comfort, energy consumption reduction due to advanced plant installed, CO_2 reduction achieved through the implementation energy solutions adopted, and the behavior achieved by implementing sustainable strategies.

	Meyer Children's Hospital, IT		Fachkrankenhaus Nordfriesland, D		Aabenraa Hospital DK		Deventer Hospital, NL		Torun City Hospital, PL	
Primary energy [kWh/(m^{2}a)]	Before	Newly built	Before	Newly built	Before	Reno-vated	Before	Newly built	Before	Reno-vated
Thermal energy	212.5	132.2	214.4	116.6	84.3	58.6	278.2	154.0	359.8	193.1
Electricity	145.6	97.00	173.4	158.4	293.6	273.0	196.8	173.5	113.8	113.8
Total primary energy	358.1	229.2	387.8	275.0	377.9	331.9	475.0	327.5	473.6	306.8

Table 1 – Primary energy before and after renovation/newly built [5]

Case studies	Energy solutions adopted	Energy consumption	CO_2 emission reduction
Italy: Meyer Children's Hospital, Florence	✓ Green roof ✓ Photovoltaic façade ✓ Solar ducts ✓ Thermal insulation ✓ Green houses ✓ Shading devices ✓ Green building design ✓ Lighting strategies ✓ Natural ventilation	The hospital consumes 40% less energy for heating and cooling and electricity, than a standard newly-built Italian hospital. The total annual electricity demand is 12.3 kWh/m².	Annual 899 tons CO2, 0,77tons SOx, **7,91**tons NOx. This is **-36**% from the average Italian
Germany: Fachkrankenhaus Nordfriesland,	✓ Double skin Façade ✓ river and rain water capture techniques ✓ solar mass wall with transparent insulation	Energy savings are approximately 46% in the renovated buildings, and new buildings use 30% less energy than standard newly-built hospitals	Annual -262 tons CO2, -0,23 tons SOx, -0,002 tons NOx. This is 46% from the average German hospital.
Denmark: Aabenraa Hospital	✓ day-lighting ✓ hybrid ventilation - natural fan assisted natural ventilation ✓ glazed courtyard	Energy savings are approximately 36% in the renovated buildings, and new buildings use 7% less energy than standard newly-built	Annual -974 tons CO2, 0,18 tons SOx, 1,59 tons NOx. This is 60% from the average Danish hospital.
Netherlands: Deventer Hospital	✓ Green roof ✓ Heat recover ✓ good insulation ✓ natural ventilation. ✓ alternative renewable energy sources, ✓ heat-cool storage and heat pumps and the application of heat recovery in ventilation exhaust.	The energy savings in the new hospital are 47% on heating and 13% on electricity compared to a standard hospital. This reduction of energy equals the reduction of 1.943 ton CO2 per year, as well as an important reduction in related emissions, e.g. 8.71tons of SOx, and 3.35tons NOx.	Annual -1.943 tons CO2, -8.71tons SOx, -3.35tons NOx. This is -69% from the average Dutch hospital.
Poland: City Hospital Torun	✓ upgraded insulation room temperature controls ✓ modern heaters, ✓ advanced valves	Energy savings are approximately 30% in the renovated buildings, and new buildings use 54% less energy than standard newly-built hospitals.	Annual -3.537 tons CO2, 116 tons SOx, 9 tons NOx. This is -50% from the average Polish

Conclusions

Demonstration with pilot projects that energy efficient and sustainable hospital buildings can fully meet all the architectural, functional, comfort, control and safety features through the application of innovative and intelligent design and integrated design.

A very high insulation level, with a U-value for the walls between 0.2 W/(m²K) and 0.3 W/(m²K), for the roof between 0.12 and 0. 8 W/(m²K) and for the windows between 1.3 and 1.8 W/(m²K) (except Meyer Children's Hospital with 3.2 W/(m²K)), ensured a low energy demand.

As a result of the planning for the hospital projects, we can state that they comply with the requirements of the project, the reduction of primary energy on average by about 30%.

Between 46 kWh/(m²a)to 170 kWh/(m²a) primary energy can be saved. The primary energy saving for heating is between 26 kWh/(m²a) and 170 kWh/(m²a).The average reduction in air pollution is about 26% for CO2 and 23% for SO2 and NOx.

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Aabenraa hospital was a part of the EU-HOSPITALS the project's technical coordinator, Esbensen Consulting Engineers, applied Integrated Energy Design (IED).
In the Meyer Children's Hospital project, thanks to a TESIS/ABITA experimental research programme, the European Community financed the incremental cost of the innovative technological and environmental solutions which were implemented in the project, monitoring the effectiveness of the results retrospectively. In particular, the experiments involved the bioclimatic greenhouse, the photovoltaic system integrated into the translucent wall of the greenhouse, the Solar Tube systems to capture and transfer the sunlight into functional environments so as to reduce electricity consumption, the innovative solutions of the green roof, and the environmental insertion of the complex into the landscape.

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