

# Successful energy efficient building renovation at state schools

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## Abstract

The project's starting point was the thesis, that a large potential to make schools more energy efficient do exists, which could enable economic profits. However the budgetary situation of the local authorities and the existing administrative structure prevented necessary action.

The authors developed the "Solar&Save" concept for realizing the saving potentials in public buildings and proved that the combination of solar energy with energy- and water savings can be economically profitable.

In the meantime, four schools have been retrofitted with energy saving measures and have been equipped with solar PV energy. Besides retrofitting the lighting system by high efficient luminaires and control systems, efficiency improvements have been undertaken for the ventilation, pumps and the heating system. In three schools combined heat and power plants (50 kWelectric) have been installed.

The total investment in the four schools was 3,2 Mio. Euro. Two thirds of the investment came from citizens of the involved cities and other private investors; one third was covered with a loan from the bank.

The return of investment was between 5 and 10 % per year, in two of the schools, and a CO<sub>2</sub>-reduction of more than 80 % could be achieved.

The pupils and teachers have also been involved in the project and now benefit from its financial success. They are

taught about the new efficiency technologies and sustainable energy resources in their schools.

The project could be transferred to other cities in the State and in other European countries.

## Introduction

One of the biggest obstacles for the implementation of energy efficiency in public building is – beside a lack of motivation and incentives in the existing administration structure - due to the scarce funds from the local authority budget. For several school buildings in North Rhine-Westphalia a financing scheme using private capital has been applied successfully in the last years. Interested citizens invest in solar and energy saving measures and within the duration of the project they retrieve their capital (plus return) through the achieved energy cost savings. In the meantime, the successful Solar&Save pilot projects of Wuppertal Institute have shown that the approach is viable.<sup>1</sup>

Public buildings in many cases are truly „devouring“ energy: the building stock is old and badly insulated in terms of heat, the heating and lighting equipment is technically outdated and was installed in times, when energy saving was not yet an issue. Energy efficient renovation is therefore urgently needed – not only to relieve the environment, but also to disburden the public budgets, for which the rising expenditures for energy are becoming a problem.

In a pilot project at four North Rhine-Westphalian schools, the main obstacle hindering energy renovation – i.e. the financing of the necessary measures – has been removed by using a special contracting scheme. In each case a multitude of private investors commits to financing a concrete renovation programme and in return receives a dividend. This so-called


Willibrord High School in Emmerich/Rhine				
	<b>Building owner</b>	Municipality Emmerich		
	<b>Year of construction</b>	1975		
	<b>Total area</b>	14.500 m <sup>2</sup>		
	<b>Number of pupils</b>	700		
	<b>Operating time</b>	8-10 hours/day 5-6 days/week		
	<b>Duration of project</b>	2003 to 2005		
	<b>Total expenditure of project</b>	641.000 Euro		
	<b>CO<sub>2</sub>-reduction/year (in 2004)</b>	<b>472.000 kg</b>		
Savings of energy and water consumption in 2004				
	Before measures	After measures		Savings in %
Electricity consumption/year	450.000 kWh	196.000 kWh		<b>56 %</b>
Heat consumption/year	1.931.000 kWh	1.323.000 kWh		<b>32 %</b>
Water consumption/year	980 m <sup>3</sup>	780 m <sup>3</sup>		<b>20 %</b>

Figure 1: Realised savings at Willibrord High School, Emmerich. (Source: Wuppertal Institute 2004, own elaboration)

„citizen contracting“ has made it possible in the past years that in four schools, located in Engelskirchen, Emmerich, Gelsenkirchen and Cologne, new building services could be applied, allowing the installation of large solar power systems (with a capacity of 20 to 50 kW) on the roofs, for a total investment of more than 3 million Euro. The buildings have also got optimised heating and ventilation systems, good light, a considerable solar power production and most notably they cause much lower energy bills for the local authorities.

#### THE CONCEPT OF SOLAR&SAVE

The concept of the Solar&Save projects is based on the awareness that in most cases efficient energy usage is cost-effective. In spite of this, the necessary energy renovation is not realised in many public properties for various reasons. This leads to a growing hold-up situation in terms of modernisation and maintenance - a situation that inevitably compels to act. This is why, in the year 2000, the Wuppertal Institute for Climate, Environment, Energy, a non-profit research institution of the land North Rhine-Westphalia, has started a project, with financial support from the Düsseldorf “Ministry for Economy, Medium-sized businesses and Energy”, aiming at the enhancement of energy efficiency at state schools<sup>2</sup>. The scheme as a whole entailed pilot projects at four schools, out of which the measures at Aggertal High School in Engelskirchen and at the Willibrord High School in Emmerich/Rhine have already been completed, and thus a final assessment can be made here (see the data of the latter in fig. 1). In Gelsenkirchen (Bergerfeld comprehensive school) and Cologne (European school) the photovoltaic installations have been operating since mid 2005, and for the beginning of 2007 the completion of the renovation measures can be expected.

The measures were realised within the framework of the North Rhine-Westphalian “100,000 watts solar programme”

supported by the Ministry of Economics. The basic idea of the “100,000 watts solar programme” is to install 50 W of solar power production and to save 50 W of lighting capacity per student at selected schools in North Rhine-Westphalia. Thus an overall 100 W capacity of conventional power production per student becomes obsolete. When schools have about 1,000 students, each school can be turned into a 100,000 W-saving solar power plant. However, the actual savings per student and school were significantly higher, since in all four schools additional economically interesting saving potentials could be exploited.

Sustainable technologies are being used in the following six fields:

- Photovoltaic power plants (20 to 50 kWp<sup>3</sup>)
- Energy efficient lighting systems with good, flicker-free light in classrooms, faculty rooms, Auditorium, gym, halls and adjacent rooms. In most cases “T5 technology” with electronic ballast and control system have been used.
- In the field of heating: improvement of the heat flow distribution in the building, including balancing of flow rates and reduction of pump power; introduction of building energy management systems (DDC).
- Reorganisation of ventilation technology and control
- Development of further economic potential for energy efficiency
- Measures for water saving.

A special characteristic of the project is the fact that Solar&Save measures are realised as “green investment” opportunities, which every interested citizen can participate in. The entrepreneurial framework is constituted by a contract between the respective Solar&Save corporation as investor and the respon-

sible local authority as school maintaining body; this special agreement is called “contracting”.

### **CONTRACTING – SETUP AND FUNCTIONING**

“Contracting” is a services concept aiming at efficiency improvement of energy producing and energy consuming installations. Often the terms “third party financing” or “performance contracting”<sup>4</sup> are also used to describe the same concept. If, for example, a local authority doesn’t want to carry out the necessary operations for improving building energy efficiency itself, because the administration is lacking sufficient know-how in terms of the technical and economic requirements of such a project, it can involve a so-called “contractor”. This contractor delivers all energy-related services (e.g. the installations for heating, ventilation and lighting of the school) from one source. In order to do this, he first designs all relevant technical systems in a way that their operation will cause the least possible energy and other operational costs. The contractor’s services (planning, implementation, investment, financing, system operation) are financed through the saved energy and water costs.<sup>5</sup>

For the duration of the project the respective Solar&Save corporations and the local authorities as school maintaining bodies conclude contracting agreements. The agreements, which are set out in writing, ensure that there is planning reliability for all parties involved until completion of the projects. The relevant contents of the contracts refer to the following regulations:

- The respective Solar&Save Contract Corporation invests into the solar power installation, as well as into technical measures for reducing energy and water consumption.
- The local authority transfers the saved energy and water costs to the responsible Solar&Save Contract Corporation.
- The achieved savings in kWh in the fields of heating and electricity are rated in current energy prices and recompensed accordingly.
- Schools and local authorities participate in the saving profits.
- The duration of the contract is 20 years (with exception of Cologne: 14 years).
- The local authority provides the school roof as base for the installation of a photovoltaic power system free of charge.
- At the end of the contract’s duration a transfer of possession of the installed Solar&Save systems to the local authority is effected.

### **SAVINGS POTENTIAL**

Today, energy efficient new buildings only need about one tenth less energy than buildings from the 1960s and 1970s. Generally, it is possible to achieve a heating energy consumption of less than 30 kWh per square meter of living space through good heat insulation, thermal protection windows, passive solar energy use and building ventilation control. In principle, this calculation is also valid for office buildings, schools and other non-residential buildings.

However, energy savings can not only be achieved in new buildings. Through well planned and carefully implemented energy saving measures, large reductions in terms of heat and electricity consumption can be achieved in both existing schools and other buildings.

In the past, these opportunities have been used only very insufficiently. Due to rising energy prices, this has recently led to exploding operational costs in many buildings. However, this rude awakening would not be necessary: economically exploitable saving potential can be found in almost every building. In connection with this, a layman would usually first think of heat insulation and an exchange of windows. However, these measures generally are only cost-effective, if they can be connected with maintenance or renovation measures, which would have been necessary anyway, like e.g. an outer shell renovation of the building. In this case, only the energy-related additional costs (for the installation of heat insulation or the extra costs for highly efficient windows) have to be taken into account, when calculating the economic effectiveness.

However, energy saving measures other than an outer shell renovation are a lot more interesting economically. Three out of many possibilities<sup>6</sup>, which have been realised within the framework of Solar&Save projects, shall be described here briefly:

#### **Improvement of heating and ventilation control systems**

Particularly in buildings with bad heat insulation and large heat losses through the outer shell, it is very important to only heat the rooms when they are actually being used. School classrooms are only used for an average of about 15 % of the time due to weekends and evening hours, as well as school holidays. However, in practice they are heated during 40 to 100 % of the time. Through an intelligent, reasonably programmed heating control system it can be achieved that heating is limited to the actual using times, and therefore heat losses caused by heating and ventilation are minimised. For example, the usage of CO<sub>2</sub> sensors can ensure that rooms are only ventilated, when air quality drops under a certain level. This usually means that they are only ventilated, when they are actually being used.

Heat supply can be controlled in an optimal way via a modern DDC-technology (Direct Digital Control). The retro-fitting with a DDC system has been one of the most economically effective energy saving measures in the schools of the project. But also in buildings, where a complex automatic control technology is already installed, saving success can still be achieved in many cases: control systems are only rarely programmed in an optimal way in terms of efficient energy use.

#### **Necessary hydraulic calibration**

Efficient heating control requires that the necessary amount of heat is brought specifically to the rooms in which it is needed. However, in many heating systems this is not the case: the profiles of the pipes and the flow rate of the radiators and fittings on the one hand, and the heat requirements of individual rooms and floors on the other hand, are often not coordinated accordingly. Since the heating water always flows through the system following the path of least resistance, such radiators which are closest to the circulating pump are overfed, while such that are farther away do not reach the necessary temperature. In this case, actors usually help themselves in practice by installing stronger pumps, or the janitor turns up the flow temperature

until the colder areas reach the desired room temperatures. This results in higher energy consumption, flow noises in the heating system, and in parts also in overheated rooms. Nevertheless, it still happens that individual rooms or groups of rooms are not heated sufficiently.

Therefore, it is inevitable for a reasonable system operation that the hydraulic conditions within the piping are adjusted to the actual requirements. For this purpose, a detailed recalculation of the pipe grid, an exact specification of the heat requirements of rooms, a recalculation of the existing radiators, and often also a change of the hydraulic system concept is required. This can result in a significantly improved functioning of the heating system with much smaller pump energy effort at the same time. In this way the Solar&Save projects in Emmerich and Engelskirchen have reduced the number of pumps to one tenth and cut down their electricity consumption by about 85 % to 90 %.

A reasonable operation of a DDC system for the automatic control of the whole heating installation entails a hydraulic calibration of the heating system. With the hydraulic calibration and the control system savings of 15 to 30 % of heat have been reached in the Solar&Save projects.

#### More light with less capacity

In the lighting industry, significant progress in terms of improving energy efficiency has been made over the past ten years. Today, it is thus possible to achieve a comfortable lighting situation of classrooms or work stations with considerably less electricity used. The key actions are:

- Substitution of electromagnetic control devices with electronic ballasts, use of highly efficient reflector louver luminaires, adoption of triphosphor tube fluorescent lamps (T5 technology)<sup>7</sup>,
- the use of presence detectors, which ensure that lighting is only switched on when users are actually present;
- the installation of daylight sensors, which guarantee that artificial light is only switched on when daylight input is not sufficient, or respectively that only as much artificial light is added as is needed for the required lighting level.

If these measures are added up, a total of 60 to 80 % of electricity has been saved, compared to the former lighting system in the schools.

An exchange is especially cost-effective in buildings, where long on-periods of the lighting systems prevail. So the retrofitting of the gymnastic hall was cost-effective in all schools, while the refurbishment in the classrooms had an amortisation time of more than 10 years.

When assessing the economical effectiveness of the new lighting systems, it is important to also take into account the significantly reduced maintenance costs of these systems.

#### EXPERIENCES OF IMPLEMENTATION IN SCHOOLS

In order to develop an economically viable refurbishment concept, it was vital to exactly determine the need for renovation at the four Solar&Save schools. This exact analysis included a detailed investigation of the current condition and way of operating of the technical installations of the building, like e.g. lighting, ventilation and duct system, heating hydraulics and

circulating pumps, automatic control systems, as well as centralised heat supply. Apart from that, the existing contract situation was analysed, as were the prices for gas, electricity, water and waste water. Based on the findings of this process, on the results of measurements of individual installations, as well as on consumption data, a relatively precise picture of the consumption situation and the previous operation of the system could be developed. Following that, a comprehensive renovation concept determined the economically feasible measures.

An energy efficient renovation and improvement of buildings requires the assignment of specialists. The practice shows that forward-looking, economically effective concepts, which lead to a significant reduction of energy costs, can be realised. At the same time, it is possible to improve the learning and working conditions through better lighting and comfortable room temperatures, which leads to an expected enhancement of motivation and labour productivity.

A breakdown of the financing concept, which is similar for all Solar&Save measures, reveals the following picture – here using exemplary figures of Willibrord High School in Emmerich/Rhine:

• Citizen investment	380,000 EUR,
• KfW Bankengruppe funds	111,000 EUR,
• Grants from REN programme <sup>8</sup>	60,000 EUR,
• Bank loan	90,000 EUR,
thus adding up to a total investment of	641,000 EUR.

#### WIN-WIN SITUATION: ALL INVOLVED PARTIES BENEFIT

The realisation of Solar&Save projects leads to classic win-win situations for all involved parties.

- The schools, which are local authority property, are reorganised in an energy efficient manner without denting the local authority's budget.
- The cities benefit additionally, since the fascination which springs from solar energy and modern technologies for rational energy use usually radiates throughout the whole municipality. Above that, the energy related operational costs of schools are widely reduced, since e.g. a new lighting system needs about 80 % less maintenance effort due to fewer and more long-lasting illuminants.
- Schools are equipped with modern and economical lighting. Learning conditions for the pupils are significantly improved by flicker-free lighting. The humming sounds, which often came along with former lighting, are no longer an issue.
- Pupils and teachers, as well as parents, learn about the careful usage of energy and water resources. The realised measures provide a demonstrational impact for the advantages and economical feasibility of energy efficient technologies, which should not be underestimated and which reaches out far beyond the direct savings effect.
- By involving the private investors economically, their identification with the whole project is enhanced. Every share of capital is also a step towards improving one's personal CO<sub>2</sub> balance. Last but not least, the shareholders will realise

	Total net investment	Electricity savings	Heat savings	Annual solar power production	Annual CO <sub>2</sub> -reduction
	In 1,000 EUR	in % in MWh	in % in MWh	in MWh	in kg
<b>Aggertal High School, Engelskirchen</b>	419	45.5 % 68	26.0 % 222	30.4	200,000
<b>Willibrord High School, Emmerich</b>	617	56.0 % 254	32.0 % 600	38.0	472,000
<b>Berger Feld Comprehensive School, Gelsenkirchen</b>	935	48.6 % 465	18.6 % 875	22.5	750,000
<b>European School, Cologne</b>	1,230	50.0 % 800	14.0 % 608	15.6	1,500,000
<b>Total</b>	<b>3,201</b>	<b>1,587</b>	<b>2,305</b>	<b>106.5</b>	<b>2,922,000</b>

**Figure 2: Scope and impacts of measures** (Source: Wuppertal Institute 2004; own elaboration)

**Note:** The specifications for Emmerich and Engelskirchen refer to the realised savings, for Cologne and Gelsenkirchen planned figures were used. After reorganisation was completed, savings were exceeded significantly in the following year in Emmerich.

returns of 5 to 10 % from their “ethically correct” investment.

- Co<sub>2</sub> emissions at schools are reduced by up to 80 %, thus leading to a significant contribution to local climate protection. The principle of “Think globally and act locally” is put into practice here.
- For shareholders, the participation in the project works as a reinsurance against rising energy prices, since the saved kWh are always multiplied by current energy prices in the annual accounts. Therefore, higher energy prices generate accordingly higher returns on investment.
- The extensive Solar&Save measures provide positive impacts on the local and regional economy and contribute to higher employment levels.

The electricity consumption of schools is reduced by about 50 % through the implemented renovation measures. In the heat sector, the projects realise reductions of between 14 and 32 %. This and the power production of the PV and the heat-and-power-plant simultaneously leads to considerable reductions in CO<sub>2</sub> emissions: for all four schools collectively, they were reduced by roughly 3,000,000 kg per year.

**FINDINGS AND FUTURE PROSPECTS**

The reorganisation measures implemented in four school buildings in North Rhine-Westphalia are running successfully and have led to significant savings in energy consumption for the good of all participants (and of the environment!). Wuppertal Institute is planning to deliver the necessary transfer of know-how in the next phase of the project. In this process, the practical experiences of the project (technical refurbishment know-how, administration of closed Solar&Save funds etc.) shall be passed on to private contractors and local authorities, but also directly to schools and the interested public, in workshops, excursions, video documentations, presentations and lectures etc. Furthermore, Wuppertal Institute wants to investigate, in

how far the project’s idea is replicable to other objects and target groups, as it turns out that high electricity and heat saving potential, which can be developed with the dynamic renovation approach of the Solar&Save concept, can also be found in hospitals, museums and other public buildings. Financing this via a citizen contracting scheme would replace the lacking investment funds of local authorities. There are many private investors, who are willing to get financially involved with such local projects.

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## Endnotes

- 1 As soon as the success of the projects was evaluated, a project was started on european level. PRIME (**P**rivate **I**nvestments **M**ove **E**co-Power) aims at fostering private investments in integrated energy efficiency and renewable energy measures by Energy Performance Contracting (EPC). The project will prepare the ground, and promote and facilitate the application of PRIME schemes including the involvement of the users of buildings into the efforts to protect the climate. PRIME is co-funded by the European Commission within the Intelligent Energy Europe programme.
- 2 cf. [www.solarundspaar.de](http://www.solarundspaar.de)
- 3 Abbreviation of kilowatt peak, the kW peak capacity ... since the sun is not always shining with the same intensity
- 4 In the case of performance contracting the payment of the contractor is only based on the performance of the efficiency measures.
- 5 Thus, the payment of the contractor does not take place at the time of the renovation, but – according to the contract – only after that, financed by the realised savings.
- 6 Further efficiency potential springs from e.g. usage of efficient heating technology and CHP, from solar energy use, from improvement of ventilation systems and load management, and from the reduction of standby losses.
- 7 These are modern fluorescent tubes with an especially high degree of efficiency and a very natural spectrum of colours.
- 8 Support programme of the land North Rhine-Westphalia since 1987 for "rational energy use and employment of renewable energy sources"; cf. [www.ren-breitenfoerderung.nrw.de](http://www.ren-breitenfoerderung.nrw.de)