# The "ECO-Watt Project": building a Negawatt power plant in a school

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## 1. SYNOPSIS

The ECO-Watt project is an energy-saving contracting project which involves a special form of financing, namely citizen participation

## 2. ABSTRACT

To highlight the marked energy savings potential that exists in public buildings, the author developed a concept for realising this savings potential and for documenting the fact that energy-saving and climate protection measures can be economically profitable. The objective was to build a "Negawatt power plant" at a local-authority school in Freiburg, using private capital. An organisation (ECO-Watt GmbH) was created in May 1998 to implement the project. Besides retrofitting the lighting system, efficiency improvements were made to the ventilation and heating system. In addition, two solar plants (thermal and photovoltaic) were installed. The investment for the project as a whole totalled EUR 250,000.

To finance the investments, membership in the organisation was offered to interested investors, with priority given to the parents of the school's students. The ECO-Watt company pays interest on the capital according to the reduced energy costs resulting from the project. The capital will have been paid back to the investors after eight years, which is the term for the contract between ECO-Watt and the City of Freiburg. The interest rate will be between three and six percent.

The cost savings for energy and water achieved through the "Negawatt power plant" work out at more than EUR 65,000 per year. A saving of more than 350 tonnes of $CO_2$ per annum will be achieved through the project. Although the city of Freiburg derives financial benefit from the project, with cost savings of approximately EUR 500,000, it was very difficult to win the city's co-operation.

The educational component of the project ensures that the students and teachers at the school are involved in the project and benefit from its financial success. One objective is to inform students and teachers about new efficiency technologies and sustainable energy resources as well as about the necessity to save limited natural resources.

The concept developed in the Freiburg pilot project will now be multiplied in North Rhine-Westphalia.

## 3. THE IDEA BEHIND THE PROJECT

"Climate protection as a form of capital investment!" "Bringing together ecology and the economy". These were the basic ideas behind the development of the ECO-Watt project. The economic efficiency of measures to ensure rational use of energy was studied and proven at the start of the Nineties in a number of analyses by the Öko-Institut, the Wuppertal Institute and other institutions.

At the same time, encouragement for the Freiburg pilot project was gained from the success of the *Förderverein Energie- und Solaragentur Regio Freiburg* (Association for the Promotion of the Energy and Solar Agency, "Regio Freiburg"), abbreviated to FESA, and the successful co-operative investment projects running for wind power plants. Since 1994, FESA has built seven big solar plants for generating electricity (photovoltaic) on roofs

over the city of Freiburg, with an output of some 250 kW. These investments were financed by share certificates sold to 260 interested parties. This meant that all citizens basically had the opportunity to invest in a solar plant.

If a large number of citizens were already prepared to invest in solar plants, which were not cost-efficient under the conditions that prevailed at the time, then there should be no problem at all in attracting money for investment in the planned negawatt power plant. A negawatt power plant of this type was, after all, expected to operate on a cost-effective basis. Over and above this, when viewed from the ecological angle, a negawatt power plant takes preference over all other energy generation and energy conversion technologies.

The initiators[1] of the project were not so much motivated by the idea of creating a favourable form of capital investment, but rather by the aim of tapping the savings potential that existed in public buildings and documenting the cost effectiveness of the energy-saving measures to the general public. What would be more suited to this purpose than a school in which students and teachers would be able to experience the use of the energy efficiency technologies and solar energy for themselves, having these technologies vividly illustrated before their very eyes?

Since the Staudinger Comprehensive School has a reputation for its committed staff and, with its 1200 students and energy and water costs totalling approximately EUR 250,000 per year is also of an attractive size[2], a first contact was made to the head of the school. He showed spontaneous interest in the project, particularly since he had long been aware of the need for remediation of the school's energy systems. Once the municipal authorities had also given their consent to a study – after a number of toings and froings – the first step had been completed.

## 4. IMPLEMENTATION: FROM THE IDEA TO THE CONCEPT

Using resources from the nonprofit Öko-Institut, a feasibility concept was first drawn up for the project. It proved possible to show that the concept would essentially be feasible, working on the basis of energy performance contracting. There were, however, a whole series of unanswered questions and problems that had to be resolved over the period that followed, such as how to secure the project against price fluctuations, which legal form to adopt for the company, and whether the school should receive a share in the savings made on energy costs.[3]

Specific savings measures were developed on the basis of an analysis of the energy and water consumption. The electrical side and the measures in the sanitary field were planned by the Öko-Institut in co-operation with the Freiburg Engineering Consultants, SEGU. The analyses pertaining to the heat side were conducted by the Fraunhofer Institute for Solar Energy Systems (Freiburg).

Apart from the refurbishment of the lighting, the circulation pumps, and the ventilation and heating systems, the concept also included measures for saving water. Over and above this, provision was made for the construction of two solar plants (one a thermal plant and one a photovoltaic plant).

All in all, the capital investment requirements were estimated at EUR 280,000. On the basis of a cautious calculation, there would be at least EUR 60,000 per year on the income side, in the form of saved energy and water costs, to offset this investment requirement. This would be enough to allow interest to be paid on the capital, and for the capital to be paid back within a reasonable period of time.

In parallel to the planning that was being conducted at a technical level, the teachers and the parents' committee were also involved in the project. After all, the aim of the project was not only to lower energy consumption through technical measures but also to get the students and teachers interested in the subject of climate protection through selective information and organised campaigns.

## 5. FROM THE CONCEPT TO ACTUAL IMPLEMENTATION

Once it appeared that all the different aspects had been clarified to a sufficient degree, the decision was taken to go ahead with the project. Three members of the Öko-Institut staff and two people from the outside founded a company of their own, ECO-Watt GmbH, to this end. A limited commercial partnership was then set up for the project at Staudinger Comprehensive School, with the name ECO-Watt GmbH&CoKG. ECO-Watt GmbH is a full partner of this partnership and liable with its capital of EUR 25,000. The remainder of the capital comes from the limited partners, who had to be found over the period that followed.

Advertising for investors in the project started in June 1998. At least EUR 200,000 was to be attracted. The remaining shortfall was to be financed via a loan from the Öko-Bank. An information brochure was compiled to advertise the investment, focusing on the theme of climate protection as a form of capital investment and describing the project. To ensure that as many parents and teachers as possible could take part, the minimum investment sum was set at EUR 500 for this group of people. For outside investors, by contrast, the minimum investment was set at EUR 2,500, in order to keep down the administration costs. The funding was acquired via FESA and ECO-Watt GmbH.

In November 1998, the trustee, FESA, who represents the interests of the investors, was able to close the till. The necessary capital had been raised, and the investment sum stood at EUR 250,000. The City of Freiburg still needed to place its signature under the contract, however. All the contracts between ECO-Watt and the potential investors thus had to be concluded with the proviso that the contract between the City of Freiburg and ECO-Watt GmbH&CoKG had to come into being before the end of the year. Viewed against this background, the acquisition phase was highly successful.

In terms of its structure, the ECO-Watt project is an energy performance contracting project which involves a special form of financing, namely citizen participation. As with a large number of other energy performance contracting projects, this project met considerable resistance from the local authority and from politicians during the planning phase. While it is standard practice in industry for individual lines of production or services to be outsourced, the public authorities have difficulty in "letting others make savings for them". A wide range of different concerns and arguments are put forward to make energy performance contracting appear unattractive or even impossible.

After dealing with a number of such arguments in this project as well, the savings contract was concluded on time with the City of Freiburg, at the end of the year. Over a period of eight years, the ECO-Watt company will be credited with the energy and water costs that are saved by comparison to the reference consumption of previous years. This will enable it to pay interest on the borrowed capital and pay back the capital to the lenders at the end of the eight years. The way was now clear for the negawatt power plant to be built. The invitations to tender were sent out for the work that would be involved in February already, and the work was allocated to local trade enterprises at the beginning of March. The Easter holidays were used to replace the lighting system in extensive parts of the building.

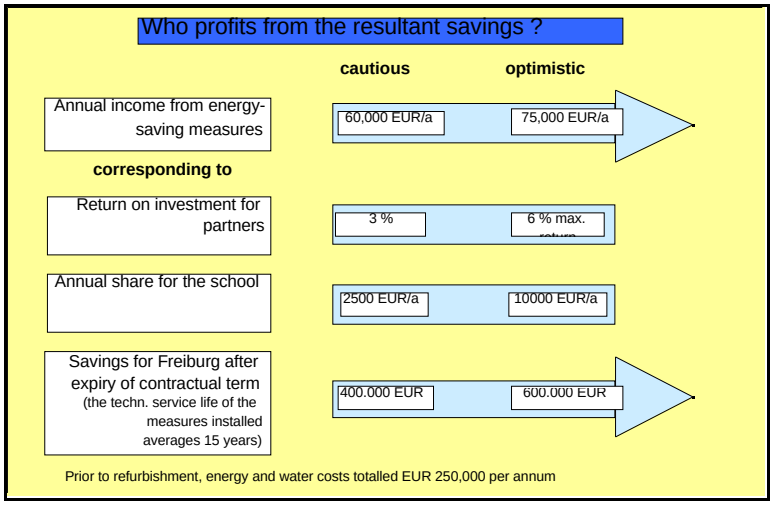
The final investment measures were implemented in the summer holidays of 1999, and since October the negawatt power plant has been running for the benefit of investors and the school alike. The school receives a sum of between EUR 2500 and 10,000 per year to spend as it likes, depending on the extent of the savings made. After the contractual period of eight years has ended, the savings will go to the City of Freiburg. Over the service life of the technologies, the City of Freiburg will realise savings of more than EUR 500,000 through this project.

## 6. BALANCING ECONOMICS AND ECOLOGY

One critical point in the implementation of energy saving projects is dividing the "profits" (the economic benefit derived from the savings measures) between the environment and the capital investors. If only the most favourable energy efficiency measures are implemented, then the amount of energy saved will be small, but the attainable profit, on the other hand, high. If less cost-efficient measures, or even uneconomical measures, are included in the overall package of measures, then the savings and hence the relief on the environment will be greater but the yield on the invested capital will fall. How was a balance achieved between economic and ecological considerations in the ECO-Watt project?

The aim was to be able to pay a minimum rate of interest of three percent per annum on the capital invested, over a term of eight years. Any energy-cost savings above the planned minimum savings will lead to a higher return on investments. In this case, the additional savings are divided between the school and the capital investors, up to the point where a yield of six percent is attained for the investors. Any costs saved beyond this are to be used for further energy-saving measures at Staudinger Comprehensive School, so that the environment benefits directly from these revenues. The allocation of the resulting savings is shown in Figure 1.

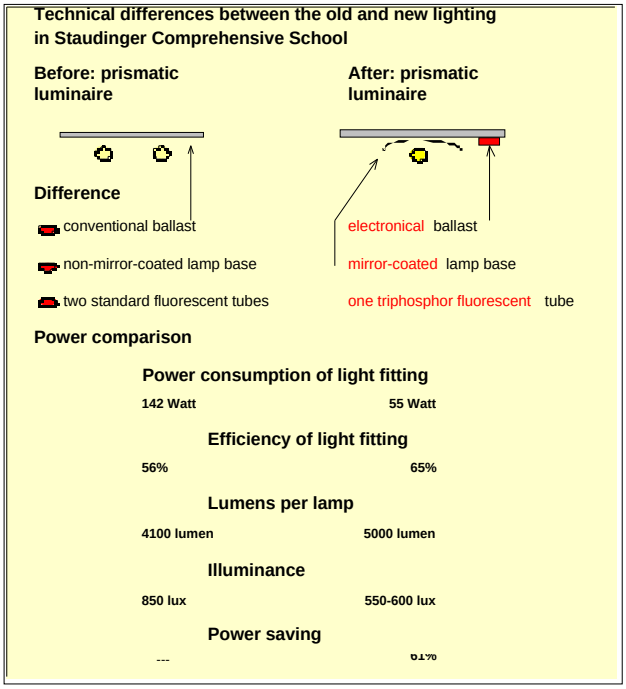
**Figure 1. Allocation of the resulting savings in the ECO-Watt project**




## 7. AN EXAMPLE: INVESTMENTS IN THE LIGHTING SECTOR

The investment in a new lighting system and in controls for the existing system constituted the biggest single item amongst the investments. Approximately EUR 100,000 was invested in this field. The measures ranged from replacement of the luminaires (for about 500 luminaires) to a daylight-dependent control system for the lighting in the gymnasium, the library and in some of the corridors. The cost-effectiveness of the different measures varied a great deal here. Figure 2 shows the lighting situation in a classroom before and after remediation.

**Figure 2: Difference between the old and the new lighting technology**



By replacing the double-lamp prismatic luminaire that had a conventional ballast and a lamp base without reflective coating with a single-lamp luminaire equipped with an electronic ballast and a reflective coating lamp base, it is possible to reduce power consumption by approximately 60 percent.[4] The triphosphor fluorescent tube that is fitted provides a pleasant light and has a high luminous efficiency in terms of its power consumption. All the luminaires in the classrooms were replaced in this way in a single construction phase. Preference was given to prismatic luminaires over mirror screen luminaires for the classrooms occupied by year-five to year-seven students, on account of their greater robustness. In the staff rooms and the library, by contrast, use was made of single-lamp mirror screen luminaires with T5 fluorescent tubes and an electronic ballast.

Table 1 shows the cost effectiveness of different measures. The cost-benefit ratio was established taking the load impact of the measures into account. The calculations are based on a six percent rate of return on investment. All the measures have been written off over a period of eight years (= term of the contract). No planning costs have been included in the calculations.

**Table1. Cost efficiency of different measures implemented in the refurbishment of the lighting system**

**Selection of measures implemented for lighting in the ECO-Watt project**
**Staudinger Comprehensive School**
**Rate of return on capital 6%, no planning costs, eight year contractual term, electricity prices as per 1998**
All prices are net prices

| Area | Measure | Power consumed before | Power consumed after | Hours of use before | Hours of use after | Total savings on electricity costs | Net investments | Investment costs apportioned on an annuity basis | Cost-benefit ratio |
|---|---|---|---|---|---|---|---|---|---|
| | | kW | kW | h/a | h/a | EUR/a | EUR | EUR/a | |
| Construction stage 2: all classrooms | Double-lamp prismatic lights replaced by single-lamp prismatic lights with electronic ballast and triphosphor tubes | 33,23 | 12,87 | 650 | 650 | 3.069 | 24.600 | 3.961 | 1,29 |
| Staff rooms | Double-lamp prismatic lights replaced by single-lamp mirror screen lights electronic ballast and triphosphor fluorescent tubes, T5 technology | 9,37 | 2,31 | 800 | 800 | 1.140 | 7.108 | 1.145 | 1,00 |
| Social rooms (billiards/youth centre) | occupancy-dependent lighting control | 1,85 | 1,85 | 1.500 | 500 | 131 | 359 | 58 | 0,44 |
| WCs | Lights replaced and controlled in 13 WCs | 4,54 | 1,76 | 2.400 | 200 | 1.115 | 5.779 | 931 | 0,84 |
| Corridors and cellar | occupancy-dependent lighting control | 0,50 | 0,50 | 2.400 | 100 | 114 | 231 | 37 | 0,33 |
| Library | Incandescent lamp spots replaced by fluorescent lamps | 1,80 | 0,27 | 500 | 500 | 154 | 415 | 67 | 0,43 |
| Library | Double-lamp prismatic lights replaced by single-lamp mirror screen lights EB and triphosphor tubes, T5 technology | 12,50 | 3,08 | 1.200 | 1.200 | 1.788 | 9.477 | 1.526 | 0,85 |
| Big gymnasium | Lighting controlled as a function of presence and incidence of daylight, switched for training/competitions | 21,00 | 21,00 | 2.500 | 1.700 | 2.110 | 8.205 | 1.321 | 0,63 |
| **Total** | **Selection of measures** | **84,8** | **43,6** | | | **9.621,1** | **56.174,4** | **9.046,1** | **0,94** |

Measures that have a cost-benefit ratio of more than "one" have to be cross-subsidised in the framework of the project. This applies to the replacement of the lighting in the classrooms, for example. Given the relatively short time for which the lighting is used, namely 650 hours per year, the lighting will not pay for itself within the eight-year contractual period. The replacement luminaires in the library, by contrast, will have been amortised after four years already.

Viewed over the period for which the technology will be in use (15 to 20 years), all the measures connected with the refurbishment of the lighting are cost-effective.

One feature of particular interest is the lighting control system in the gymnasium. This controls the lighting as a function of the incidence of daylight and is also programmed. The cleaners who work in the school in the mornings are only able to switch on a third of the lights, school sports lessons are held with 300 lux, or two-thirds of the lighting, and the full lighting is switched on for contests and particular types of sport.

## 8. COMBINING ENERGY SAVINGS AND RENEWABLE ENERGY SOURCES

A sustainable energy system must consistently tap the potential that exists for the rational use of energy and must satisfy the remaining energy requirements with renewable energy sources for the most part.

On the basis of these considerations, the energy-saving measures were supplemented by the construction of a thermal solar plant with a collector surface of 42 square metres. This covers most of the hot water requirements for the two gymnasiums. In addition to this, plans were made for the construction of a 2 kW solar plant, which was to be financed, in part at least, through subsidies and sponsorship money.

Since these plants do not pay for themselves within the eight-year term of the contract concluded with the City of Freiburg, they have to be financed through the savings made on energy costs. On the basis of the results obtained so far, a considerable increase can be expected in the share of renewable energy supplies over the next few years, given the savings that have been made. Instead of the 2 kW solar power plant that was planned to be installed, 4 kW have already been installed. Further plans have also been drawn up and are ready to implement.

## 9. THE NEGAWATT POWER PLANT: "ENERGY FOXES" BEING TRAINED

In parallel to the investments, a student/teacher study group working in co-operation with the manager of ECO-Watt GmbH conducted a large number of activities at the school to provide students, teachers and parents with information. Project days and project weeks were held on energy-specific topics, and aspects of climate protection are increasingly being treated in classes in conjunction with the use of energy. It is now standard practice in the school for children from the middle classes to introduce the new arrivals to the ECO-Watt project, explaining to them what it entails and how students can contribute towards energy saving by airing their classrooms correctly and using the light switches. To ensure that energy-conscious behaviour becomes firmly rooted in all the classes, saving competitions open to all classes are organised at Staudinger Comprehensive School.

After the negawatt power plant had been successfully started up, the training of "energy foxes" commenced in co-operation with a teacher. Students in one of the year-six classes are being trained to recognise and tap energy-saving potentials in their homes on their own. The result was impressive: almost all the energy foxes were able to track down opportunities for saving energy in their own homes. A large number of students found hidden electricity gluttons at home in the form of televisions, printers, video recorders and halogen lamps. The stand-by losses can generally be readily avoided through the use of switchable sockets. The students also frequently established a need for changes in the lighting. Many homes are still predominantly using incandescent lamps. The energy foxes completed their training with a visit to the "Solarfabrik" (solar factory) in Freiburg (Figure 3). During their guided tour, the students showed a high level of motivation and interest. School can be fun and impart knowledge with a practical bearing on life!

**Figure 3. The energy foxes visiting the "Solarfabrik" solar factory**

## 10. THE RESULTS AFTER THE FIRST YEAR IN OPERATION

Now that the negawatt power plant has been in operation for a year, it is possible to draw up a reliable interim assessment for the first time: the negawatt power plant works and it produces a rewarding yield for both the environment and the investors.

More than 200,000 kWh of **electricity** were saved over the first year[5]. The minimum savings had been estimated at 130,000 kWh in the planning phase.

The maximum wattage supplied by the municipal utility was reduced by more than 100 kilowatts. This good result was achieved through the increased efficiency of the lighting, on the one hand, and through the installation and optimisation of the new load management system, on the other.

In the **water sector** as well, the savings achieved are considerably greater than those planned. Approximately 8.5 million litres of water are saved each year as a result of the investment – representing savings of just under 70 percent compared with the consumption of past years.

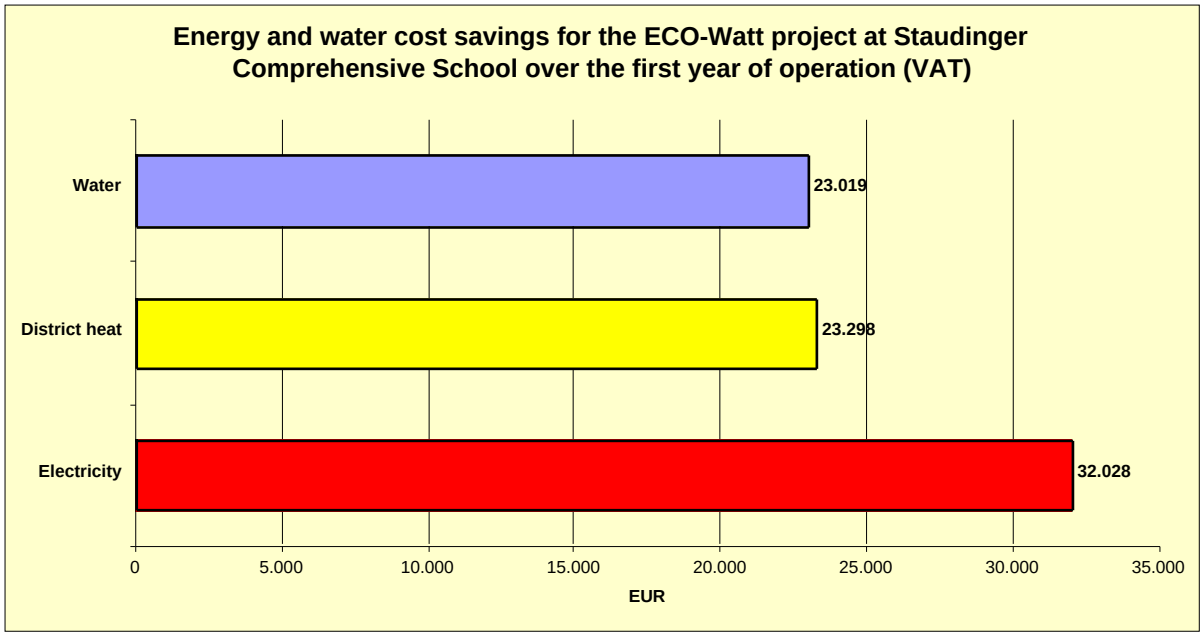
The **heat savings** accounted for some 600 MWh compared to the previous year, corresponding to a 24 percent reduction in consumption (with correction for the number of degree-days). The planned value of 30 percent was thus not fully obtained.

A total of just under EUR 80,000 gross (including VAT) was saved compared with the reference year (Fig. 4). Investors can thus reckon on receiving five percent interest on their capital. The school will receive more than EUR 7,500 per year as a result of the success in making savings.

Apart from the direct reductions in emissions achieved through the reduced use of fossil energy sources (approximately 350 tons $CO_2$ per year) the project also has a further environmental impact. By using more efficient luminaires and lamps, it has proved possible to reduce the amount of mercury used in the lighting by more than 90 percent. In addition to this, there is less work for the school caretaker when it comes to replacing defective fluorescent tubes – the reduced number of lamps and their longer service life means that less than a quarter of the previous number of replacements are required.

The savings that have been achieved have not involved any reduction in comfort - on the contrary, students and teachers are benefiting from enhanced lighting comfort. With the installation of electronic ballasts, flickering fluorescent tubes and humming (from defective conventional ballasts) are now a thing of the past.

**Figure 4. Cost savings within the first year of operation**




## 11. THE INDIRECT IMPACT OF THE PROJECT

The impact of the project is not simply limited to the direct energy savings. By informing people about the project and the results achieved, it can be shown that climate projection is not associated with high costs and deprivation. Instead, with the positive return from measures for increasing energy efficiency it is possible to finance investments in solar technology as well, while still achieving a return on the capital invested. This project is thus intended to provide a stimulus for the City of Freiburg and other local authorities and actors to follow suit.

The investment volume for the ECO-Watt project totals more than half a million deutschmarks. Almost half of this investment sum is accounted for by wages for the installation of the energy efficiency technologies, while the other half is required for the purchase of the energy efficiency and solar technology. Since Freiburg has none of the relevant branches of industry (with the exception of photovoltaic module production), this extra demand has had half its impact in the Freiburg region and half elsewhere in Germany.

Extrapolating the investment volume for this project in terms of the energy consumption at Staudinger Comprehensive School over all the public buildings in the City of Freiburg[6], we obtain a sum of more than EUR 7 million that would be available to the City of Freiburg alone and could be channelled into **cost-effective** energy efficiency technologies. This level of investment would bring the city a long-term reduction in costs and provide the Freiburg region with a sustainable stimulus for ecologically and socially compatible technologies. Savings of some EUR 25 million in the cost of energy would be achieved to set against the investments over the next 20 years.

Finally, projects of this type also have a key function for the crafts and trades. The individual companies are able to gain practical experience in the latest energy efficiency and control technologies. This is then associated with a change in the advice and the product range that these companies offer their future customers. These direct and indirect effects mean that electricity and oil imports from other regions and other countries are replaced by innovative technologies and labour. This leads to increased employment and also strengthens spending power and closed cycles in the regional economy.

## 12. FURTHER DEVELOPMENT AND DISSEMINATION OF THE APPROACH

The German state of North Rhine-Westphalia (NRW) instigated a new initiative at the start of the year, with a future-oriented project launched via its energies-of-the-future initiative and using the same approach as the ECO-Watt project. Entitled "100,000 watt solar initiative NRW", this project involves the use of the latest energy-saving and solar energy technologies in order to make schools sustainable.

What stands behind this project title? A solar plant (photovoltaic) is to be installed at as many big schools in North Rhine-Westphalia as possible, with an output of 50 watts per student. At the same time, power savings of at least 50 watts please give an idea of the relative weight per student are to be achieved through more efficient lighting and other energy efficiency measures. Most of the existing lights in the schools are to be replaced to this end – a move which will permit electricity savings of more than 60 percent for lighting. By combining the use of solar radiation with cost-effective energy-saving measures and exploiting the existing financial incentive schemes for renewable energy sources, it is possible to achieve a refurbishment and investment model which is cost-efficient per se. Similar to the ECO-Watt Project, most of the investment will be financed from private investors, predominantly the schoolchildren's parents.

The Aggertal Grammar School in Engelskirchen was selected by way of a pilot project. The Wuppertal Institute drew up the following concept for the school, which has around 700 students:

- A photovoltaic plant on the roof of the main building is to produce electricity. The plant will have an output of around 45 kW. This will produce 34,000 kWh electricity a year.
- The lighting systems in the classrooms, corridors, gymnasium and assembly hall are to be modernised. More efficient luminaires, electronic ballasts and daylight-dependent lighting controls will reduce the power rating by approximately 50 kW. The annual savings on electricity will work out at 40,000 kWh.
- A gas-fired combined heat and power plant will provide both electricity and heat for the school. This compact power plant will have an output of around 60 kW. The Aggertal power supply company will construct and finance the combined heat and power plant and will supply the power that it generates to the school (resp. the local authority), under the same conditions as beforehand. The heat that is generated will also be sold at the same price as the gas consumed beforehand.
- Additional smaller measures for saving on electricity, heat and water are designed to further reduce the school's consumption.

All in all, the energy-saving measures and solar electricity production will reduce the amount of electricity consumed from its present value of 120,000 kWh to approximately 40,000 kWh.

During the pilot study, the entire planning, scheduling and implementation of the project is being carried out by the Wuppertal Institute with financial support from the state of NRW and in co-operation with the Aggertal electricity supply company, and is being coordinated with the partners involved in the project and the Engelskirchen local authority.

As part of the pilot study, all the fundamentals are to be worked out so as to enable the project to be applied to other schools in NRW and elsewhere in Germany.

**More information**

about the ECO-Watt project: www.eco-watt.de

Umweltbundesamt: Energie-Contracting als Beitrag zu Klimaschutz und Kostensenkung. Ratgeber für Energiespar-Contracting in öffentlichen Liegenschaften. Berlin 2000 (www.uba.de)

about the author: www.oe2.de

## 13. END NOTES

[1] Still on the staff of the Öko-Institut at the time. Today the author is head of the consulting company Büro Ö-quadrat (www.oe2.de)

[2] With small projects, there is a less favourable ratio between planning and implementation costs on the one hand and saved energy-and water costs on the other

[3] The further planning work was kindly supported by the Ertomis Foundation in Wuppertal, Germany.

[4] With 550 to 600 lux, the lighting comfort of the new system is still very good and higher than the German DIN-Norm

[5] October 1999 to September 2000

[6] The City of Freiburg has a population of approximately 200,000