Improving the energy efficiency of public buildings

In a nutshell

SUMMARY
It is best practice to maximise the energy efficiency of public buildings and minimise their energy use. This can be achieved by improving the energy performance and integrity of the building envelope (walls, roof and glazing) and increasing the airtightness, as well as installing energy efficient equipment and commissioning the energy systems. Both new and existing public buildings can achieve better energy performance than the minimum standards set in the national building codes[1] and be designed or renovated as nearly zero-energy buildings (NZEB) ahead of the EU obligation[2]. When defining the measures to improve the energy efficiency of the buildings, not only the energy performance to be achieved, but also the overall environmental impacts over the whole life cycle of the buildings need to be considered[3]. These can be minimised by, among others, selecting sustainable and low embodied primary energy construction materials, ensuring, at the design phase, easy adaptability to support future re-use of the building and easy renovation (e.g. flexible floor plans) as well as the possibility to deconstruct for re-use and recycling of building materials and elements.
Target group
Local authorities
Applicability
This best practice is applicable to all public administrations provided that they can commit the required financial resources for improving the energy efficiency of public buildings. This BEMP may be more difficult to implement in rented properties. Additionally, the level of energy performance that can be achieved in each specific case will be affected by the characteristics of the building (e.g. old building).
Environmental performance indicators
• Total annual energy use per unit of floor area, expressed as final energy (kWh/m^2/year) • Total annual primary energy use per unit of floor area (kWh/m^2/year)
Bencharks of excellence
• For new builds, the building is designed with a total primary energy use (including all uses) lower than 60 kWh/m^2/year • For existing buildings undergoing renovation, the building is designed with a total primary energy use (including all uses) lower than 100 kWh/m^2/year

[1] Directive 2010/31/EU (Energy Performance of Buildings Directive, EPBD) requires Member States to set minimum energy performance standards for buildings, which need to be reflected in the national building codes. The Directive introduced a benchmarking system to gradually increase the level of ambition of these energy efficiency requirements, keeping them under regular review.

[2] The EPBD requires that all new buildings consume very low or nearly zero energy ('nearly zero energy buildings') by 2020 or by 2018 if occupied and owned by public authorities.

[3] The European Commission is currently piloting a voluntary reporting framework, Level(s), for measuring the overall sustainability performance of buildings throughout their life cycle. More info available at: http://ec.europa.eu/environment/eussd/buildings.htm

Description

Buildings are a key area of action, as they are responsible for nearly 40% of final energy consumption (and 36% of greenhouse gas emissions). Moreover, buildings provide the second largest untapped and cost-effective potential for energy savings after the energy sector itself (EC, 2013c). Public administration own or occupy a considerable number of buildings ranging across different building types: offices, schools, hospitals, warehouses etc., depending on their competencies/tasks in each country. For local authorities, public buildings are responsible for about 75% of their own direct energy consumption (ADEME, 2007).

It is best practice to maximise the energy efficiency of public buildings and minimise their energy use. This can be achieved by improving the energy performance and integrity of the building envelope (walls, roof and glazing) and increasing the airtightness, as well as installing energy efficient equipment and commissioning the energy systems.

Two cases need to be distinguished: the energy efficiency retrofitting of existing public buildings, and the construction of new nearly zero energy buildings ((NZEB). Both new and existing public buildings can achieve better energy performance than the minimum standards set in the national building codes and be designed or renovated as nearly zero-energy buildings (NZEB) ahead of the EU obligation.

Implementing several general retrofitting measures to improve building envelopes, higher energy efficiency in existing buildings can be achieved. These measures are included in Table 1 (EC, 2013b). When defining the measures to improve the energy efficiency of the buildings, not only the energy performance to be achieved, but also the overall environmental impacts over the whole life cycle of the buildings need to be considered. These can be minimised by, among others, selecting sustainable and low embodied primary energy construction materials, ensuring, at the design phase, easy adaptability to support future re-use of the building and easy renovation (e.g. flexible floor plans) as well as the possibility to deconstruct for re-use and recycling of building materials and elements.

Table 1: Retrofitting techniques for improving the energy efficiency of the building envelope

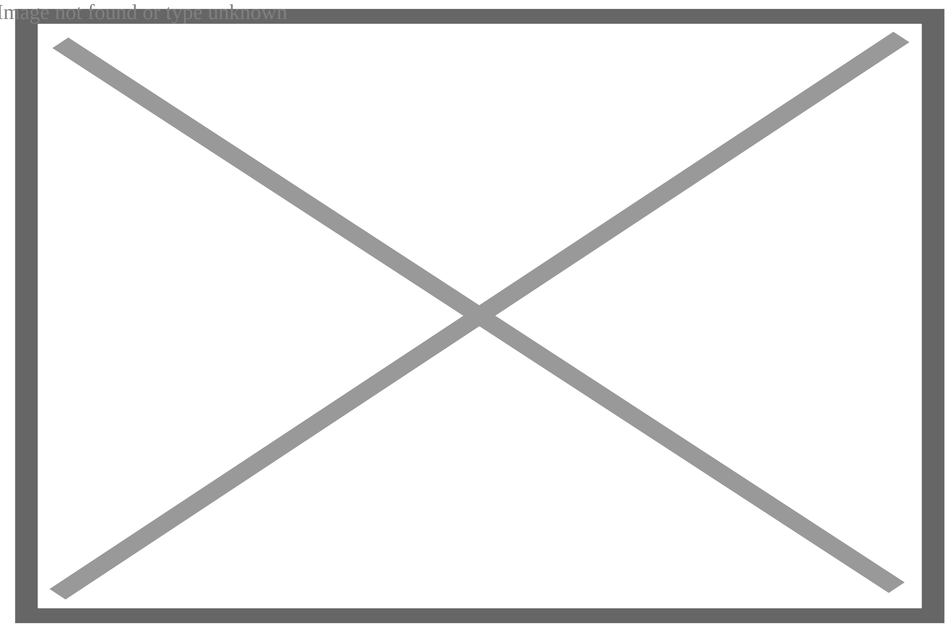
Envelope element	Technique	Description
Wall/façade/roof/floor – cellar ceiling	Change insulation materials	When an existing building is retrofitted, new and innovative r transparent insulation, vacuum insulated panels) have to be increase the insulation and save energy.
	Techniques to increase the insulation thickness	The material thickness is an important aspect of insulation. techniques are: external thermal composite system , clad circulation, cavity insulation, fixation to inner surface of walls, fla insulation, waterproofing layer, insulation of cellar ceiling, cra ground insulation, etc.
	Improving the environmental performance of roofs	Design and use cool, brown and green roofs to improve behaviour of the building, also with a positive effect on biod drainage performance and on the mitigation of heat island effec

Envelope element	Technique	Description
Windows / glazing	Change to more efficient glazing	Glazing is the use of glass panes assembled into units of tw four in order to increase its thermal and acoustic insulation pro (air) or vacuum fills the gap between two units. Multiple panes insulation without sacrificing transparency. Examples of the most common retrofitting actions are: increase in the number of panes (up to four) low-e coatings CO_2, vacuum or argon filling
	Change to more efficient sashes and frames	Change to materials for frame, sash and other window comp (high thermal performance, high cost for maintenance), alumin metals (bad thermal performance, zero cost for maintenance) (high thermal performance and zero cost maintenance, but low heat). The replacement of metal parts of the frame and the sash is practice, as it produces thermal breaks that improve insulation.
Shading	External and internal devices	Solar shading devices should allow the control of direct, diffuse solar radiation and glare. They contribute to the energy pe buildings by allowing interior exposure to low-angled sun in wi the summer sun. Sometimes they perform other roles: some as thermal barriers to prevent thermal losses. So, they h influence on the energy requirements for the heating, cooling a a building. Some of the most common external devices are: overhangs, a and vegetation, roller shutter, venetian blind, roller blind, etc. Examples of internal devices are: venetian blind, roller blind, an
Air tightness	Improvement of doors	From the energy efficiency point of view, doors are important have the same problems as portals. The most important me energy efficiency of doors is to avoid air leakage, which can acc 20 % of building heat loss. Therefore, weather stripping and se implemented following examination. For the best performance, be replaced for doors with more effective insulation (low U- Storm doors should also be used
	Fast acting doors	When a door has to be used frequently it is usually left open. huge losses of energy for heating and cooling. The use of au acting doors can produce a significant contribution to energy sa
	Sealing	Air leakages usually originate from window and door frames, lig ducts penetration, dryer ventilation, plumbing penetration outlets. These leakages can account for between 25 % and heating and cooling needs of a building. Two techniques ca reduce the air leakages from building envelope elements: wea (installation of tension seal, felt, reinforced foams, tape, reinfor sweeps, magnets, tubular rubber, reinforced silicone, door sh caulking (silicone, expandable polyurethane, butyl rubber, etc.)

Envelope element	Technique	Description
Buffer sections	The use of buffer sections, like a draught lobby for the entrances, reduces the heating and cooling needs of a building, as the rate of exchanging air with the outdoor environment is minimised. The same can be done for vehicular accesses.	
Overall envelope	Maintenance	The management techniques related to maintenances are solutions to saving energy. Some examples include: keeping main entrances and windows closed keeping the blinds opened for using natural light as much as po making regular inspections to the construction elements in o signs of damage: rips, cracks, gaps, damps, condensation

The reduction of heating and cooling energy demand is therefore achieved by employing energy efficient windows, high insulation levels and air tightness. Furthermore, active solar technologies, passive solar design techniques and water heat recycling technologies may be used.

An outstanding example of energy performance achieved in buildings is the Passive House standard and its equivalent standards. The aim of the Passive House standard is to provide an improved indoor environment (air quality and thermal comfort) with the minimum energy demand and cost, achieved improving the envelope to a point in which the heating demand becomes very low (Feist et al., 2005). For the Passive House standard, the maximum value of energy consumption for space heating or cooling is 15 kWh/m^{2}yr. This value is set ensuring that the costs are minimised when the building life cycle is analysed. Figure 1 shows the construction costs (initial investment), the energy costs during the lifetime and the total costs for buildings with different heating demands. In the chart of Figure 1, a drop at 15 kWh/m^{2}yr is observed: this point represents the minimum energy cost. Below this value, the construction costs increase due to the need of significant insulation and tightness. If the heating demand is higher than 15 kWh/m^{2}yr, the life cycle costs increase sharply (Figure 1) due to the need of more complex heating system able to provide the higher heating power needed (PassivHaus Institute, 2007). Instead, when the total installed heating power is less than 10 W/m^2 (usually when the demand is higher than 15 kWh/m^{2}yr), it can be achieved by the solar gains and a simple ventilation system.



Source: Laustsen, 2008

Figure 1: Total costs, energy costs and construction costs vs. building heat demand

Table 1 gives an overview of what other requirements define the Passive House concept and how they can be achieved (Laustsen, 2008).

Table 1: Passive House requirements and measures to achieve them

Requirements	Measure to achieve them
The building heating + cooling demand must be lower than **15 kWh/m^{2}yr**	Improved insulation. Recommended U-values less than **0.15 W/m^{2}K**
The specific heat load should be less than **10 W/m^2**	Design without **thermal bridges** Windows U-values lower than **0.85 W/m^{2}K**
The building must not leak more air **than 0.6 times** the house volume at the 50 Pa test (n_{50} value)	Air tight. **Mechanical ventilation** with heating recovery from exhaust air
Total primary energy demand cannot be more than **120 kWh/m^{2}yr**	**Innovative heating technology** (renewable sources would account for 0 kWh/m^{2}yr of consumption)

Another set of exemplary standards for buildings, called Minergie, were developed in Switzerland and has been quite successful in its application, even outside Switzerland. The Minergie-P standard uses a similar approach to the Passive House. Figure 2 shows a comparison of the requirements and differences between Minergie and Minergie-P. One of the outstanding characteristics of Minergie is the development of a concept seeking comfort and energy efficiency, with a main feasibility approach stating that the actual costs should not be more than 10 % of the costs of the construction of an average building fulfilling legal requirements. Minergie develops the requirements for the primary energy consumption of the heating system, taking into account the efficiency of the heating system, hot water demand and the electricity used for ventilation. This should be taken into account when comparing with the Passive house standard, which sets thresholds only for the demand.

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Source: Minergie, 2010

Figure 2: Summary of requirements for Minergie and Minergie-P

For new and existing buildings, the Passive House, Minergie and Minergie-P concepts are outstanding examples for energy efficiency. Reference values are given in Table 3.

Table 3: Different exemplary approaches and the associated requirements (EC, 2013)

Approach	Residential	Non-Residential
Passive House (New)	Heating: 15 kWh/m^{2}yr (cooling 15 kWh/m^{2}yr or heating + cooling = 15 kWh/m^{2}yr, see Passive-On, 2007)	Heating: 15 kWh/m^{2}yr (cooling 15 kWh/m^{2}yr or heating + cooling = 15 kWh/m^{2}yr, see Passive-On, 2007)
Passive House (Existing Buildings)	Heating: 25 kWh/m^{2}yr	Heating: 25 kWh/m^{2}yr

Minergie-P (New- Buildings)	HVAC and DHW primary energy consumption: Residential, 30 kWh/m^{2}yr	HVAC primary energy consumption: Public administration, schools, commercial 25 kWh/m^{2}yr Restaurants, 40 kWh/m^{2}yr Hospitals, 45 kWh/m^{2}yr Industry, 15 kWh/m^{2}yr Warehouse, 15 kWh/m^{2}yr Sports, 20 kWh/m^{2}yr
Minergie (Existing Buildings)	HVAC and DHW primary energy consumption: 60 kWh/m^{2}yr	HVAC primary energy consumption: Public administration, schools, commercial 55 kWh/m^{2}yr Restaurants, 65 kWh/m^{2}yr Hospitals, 85 kWh/m^{2}yr Industry, 40 kWh/m^{2}yr Warehouses, 35 kWh/m^{2}yr Sports, 40 kWh/m^{2}yr
N.B. HVAC: Heating, Ventilation and Air Conditioning; DHW: Domestic Hot Water		

Environmental benefits

The main environmental benefit achieved with very high energy performance public buildings is the reduction of the primary/useful/final energy demand, e.g. for space heating/cooling, water heating, air conditioning as well as a reduction in the consumption of electricity (EC, 2013a).

Table 4 provides some definitions and specific energy demands for low energy buildings in selected EU member states.

Table 4: Examples of definitions for low energy building standards (Engelund Thomsen et al., 2008; EC, 2009)

Country	**Official Definition**
Austria	• Low energy building = annual heating energy demand below 60 – 40 KWh/m^2 gross area (30 % better than standard performance) • Passive building = passive house standard: 15 kWh/m^{2}yr per useful area and per heated area
Belgium (Flanders)	• Low Energy Class 1 for houses: 40 % lower than standard levels, 30 % lower for office and school buildings • Very low energy class: 60 % reduction for houses, 45 % for schools and office buildings

Czech Republic	• Low energy class: 51-97 kWh/m^{2}yr • Very low energy class: below 51 kWh/ m^{2}yr, also passive house standard of 15 kWh/ m^{2}yr is used
Denmark	• Low Energy Class 1 = calculated energy performance is 50 % better than the minimum requirement for new buildings • Low Energy Class 2 = calculated energy performance is 25 % better than the minimum requirement for new buildings (i.e. for residential buildings = 70 + 2200/A m^{2}yr where A is the heated gross floor area, and for other buildings = 95 + 2200/A m^{2}yr (includes electricity for lighting)
Finland	• Low energy standard: 40 % better than standard buildings
France	• New dwellings: average annual requirement for hot water, heating, ventilation, cooling, and lighting have to be to be lower than 50 kWh/m² (in primary energy). This ranges from 40 – 65 kWh/m² depending on the climatic area and altitude. • Other new buildings: average annual requirement for hot water, heating, ventilation, cooling, and lighting has to be 50 % lower than current Building Regulation requirements • Renovation: 80 kWh/m² as of 2009
Germany	• Residential low energy building requirements = KfW60 (60 kWh/ m^{2}yr) or KfW40 (40 kWh/ m^{2}yr) maximum primary energy demand • Passive house = KfW40 buildings with an annual useful energy demand for space heating lower than 15 kWh/ m^{2}yr and total primary energy demand lower than 120 kWh/ m^{2}yr
England & Wales	Graduated minimum requirements over time: • 2010 level 3 (25 % better than current regulations), • 2013 level 4 (44 % better than current regulations and almost similar to passive house) • 2016 level 5 (zero carbon for heating and lighting), • 2016 level 6 (zero carbon for all uses and appliances)

Figure 3 shows the differences in the primary energy consumption between Passive House Standard buildings and the reference buildings built according to existing regulations. It is clearly noticeable the significant reduction (55-60%) of primary energy consumption of the buildings employing Passive House standard compared to the ones built according to existing regulations (Feist et al., 2005).

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Figure 3: Comparison of primary energy consumption of Passive House projects with new buildings meeting existing energy requirements

Side effects

Embodied energy of buildings is an aspect concerning the life cycle energy assessment. However, operating energy remains the main energy required (usually about 80-90%) while embodied energy is about 10-20% (Ramesh et al., 2010) as presented in Figure 4.

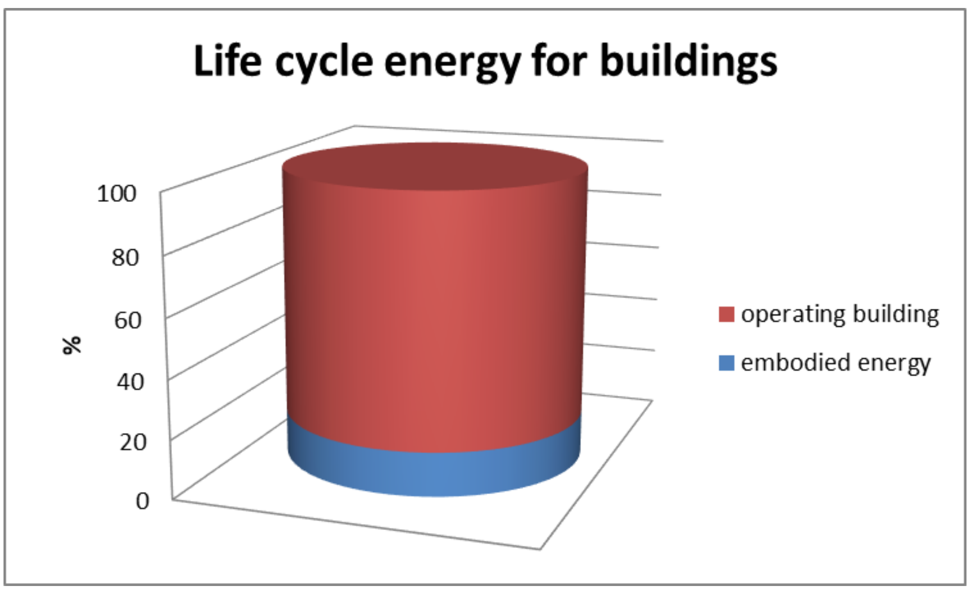

Figure 4: Life cycle energy for buildings: operating and embodied energy

When looking at cross-media effects, the use of passive house (or an equivalent standard to reduce the overall life cycle impact of a building) is usually regarded as increasing the embodied energy of the building. However, the increase in embodied energy between buildings meeting the current regulations and the ones built according to the passive house standard is limited. In fact, it has been reported that embodied energy was 1171 kWh/m^2 for normal buildings and just 1391kWh/m^2 for the Passive House buildings (Feist, 1996). Therefore, with an increase of 15-20% in the embodied energy a Passive House can reduce 55-60% of the primary energy consumption of an equivalent conventional building (Feist et al., 2005). Finally, when choosing the construction materials, reuse, recycling and greening the supply chain should also be a concern, and not only their embodied energy.

Applicability

This best practice is applicable to all public administrations provided that they can commit the required financial resources for improving the energy efficiency of public buildings. This best practice may be more difficult to implement in rented properties. Additionally, the level of energy performance that can be achieved in each specific case will be affected by the characteristics of the building (e.g. old building).

Economics

In all cases, the additional costs for low energy buildings depend on specific conditions, but the extra upfront investments are about 10 % or less, with a clearly declining trend. Energy prices, labour cost, available experience, expertise and the way in which each construction project is executed differ significantly from one country to another, so that the transfer of cost estimations should be treated with caution. Especially, the transfer of price estimations from countries with an advanced diffusion of low energy buildings, such as Germany, to countries just beginning diffusion can be misleading. However, in general, the additional investment will be in the range of 100 EUR/m² or less (Lenormand et al., 2006) (more if expensive solutions are used), with payback returns of less than 20 years. Laustsen, 2008, also gives some important economic data.

Some data were published in 2007 for the economic performance of the construction of Passive Houses in Europe (Passive-On, 2007). Data are shown in Table 9.

Table 9: Economic performance estimation of Passive House standards application in Europe (Passive-on, 2007)

Item	**France**	**Germany**	**Italy**	**Spain (Granada)**	**Spain (Seville)**	**UK**
Extra capital cost (EUR/m^2)	103	94	60	24	20.5	73
Extra capital cost (%)	9 %	6.7 %	5 %	3.3 %	2.8 %	5.54 %
Energy savings, kWh/m^2yr	55	75	86	65.5	38	40
Life cycle cost (LCC) 20 years, standard construction, EUR	160300	204900	221000	118000	109000	118000
LCC 20 years, passive construction, EUR	160500	200600	198460	104000	102300	117000

Item	France	Germany	Italy	Spain (Granada)	Spain (Seville)	UK
Discounted payback time, years	19.5	19	8	4	5	19

There are two main characteristics of Passive House economics for new buildings: construction costs are relatively similar and only a 5 to 10 % increase is observed. Energy savings are significant, but payback time periods can be long for countries with better building practice traditions or standards. For Italy and Spain, current building practice would really benefit from the standard, with short payback periods.

According to the results, a variation from 8 to 17 % extra costs were observed in 2001. It was reported (Feist et al., 2005) that cost prices per kWh of energy saved where less than EUR 0.06 (uniform real interest rate of 4 % and service life of 25 years, taking into account the maintenance of equipment, the cost of electricity for ventilation and additional operating cost savings).

The main conclusion from the application of the Passive House standard or any other equivalent is that they will always payback investment costs for public buildings, when compared to current building practices.

Driving forces for implementation

The crucial importance of energy savings from energy efficiency in buildings has been recognised by the energy performance of building directive (EPBD) in 2002 and its recast in 2010 (regulation (EC) 31/2010). In this directive it is stated that all new buildings, starting from 31st December 2020, should be 'nearly zero energy buildings' and public authorities that own or occupy a new building should set an example by building, buying or renting such 'nearly zero energy building' from 31st December 2018. The definition of very low energy building was agreed to: "nearly zero energy building means a building that has a very high energy performance, determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant level by energy from renewable source, including renewable energy produced on-site or nearby". The directive also tackles existing buildings inviting Member States to develop policies and adopt measures to stimulate the transformation of refurbished buildings into very low energy buildings.

Furthermore, local authorities may increase the energy efficiency of their buildings when deciding to take part in voluntary schemes aimed at reducing the carbon footprint of municipalities. The Covenant of Mayors, for examples, requires municipalities to establish a sustainable energy action plan (SEAP) where the municipality presents all the actions which will be taken for reducing greenhouse gases emissions and measures for increasing energy efficiency in buildings can also be included.

Moreover, energy bills for municipalities are an important chapter in their annual economic balance. Therefore, reducing the energy bill is also a driving force for implementing measures aimed at improving the energy efficiency and this was also the case for the municipalities of Olbersdorf and Frankfurt. Paybacks times, as seen in the economics section, are reasonable for public buildings which aim at being operational for many years. Moreover, reduced energy consumption produces other benefits to local communities which are therefore also driving forces for implementation: reduction of CO_2 emissions, job creation, enhanced thermal comfort and indoor air quality in buildings and consequently health improvements.

Reference organisations

In Germany, the **Passive House Institute** (PHI) is an independent Research Institute engaged in the research, development and promulgation of building concepts, building components, planning tools and validation for particularly energy efficient buildings: www.passiv.de

In Switzerland, the **Minergie Standard** can be easily met within central Europe in the design of building structures and the choice of materials. Economics is also considered within the standard: the budget for a certified new building (or for the renovation) should not exceed more than the 10 % of the typical cost of a similar uncertified building. The variant

Minergie-P is considered as the equivalent to the Passive House standard: http://www.minergie.ch/home_en.html

Build up, the European portal for energy efficiency in buildings. A portal bringing together policy makers, building professionals and building occupants, reporting many examples and details of successful energy efficient buildings (new or renovated): http://www.buildup.eu/

Display Campaign, an initiative aimed and raising awareness of citizens about energy efficiency in buildings, by encouraging local authorities to publicly display the energy and environmental performances of their public buildings. Many successful examples of efficient public buildings are presented: http://www.display-campaign.org/ab_839_942

Olbersdorf school refurbishment project was carried out by the Fraunhofer Institute for Building Physics: http://www.ibp.fraunhofer.de/en.html and the person responsible was Heike Erhorn-Kluttig.

Frankfurt Ridelberg school project was managed by the Frankfurt Energy Agency**:** www.energiereferat.stadt-frankfurt.de

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