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Ambitious renovation of a historical school building in cold climate

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Abstract

Brandengen Primary School in Norway has historical valuable buildings from 1914, designed by the famous Norwegian architect Arnstein Arneberg. The owner, Drammen Municipality, emphasizes renovation in accordance with the conservation authorities' request for restoring the façades to be as close as possible to the original historic look. To achieve future high performance building levels when renovating the school, i.e. low energy consumption and good indoor climate conditions, the main measures taken are additional insulation of attic and basement, new windows, and replacement of the oil burner with a geothermal heat pump. The target figure for energy reduction is set to 67 %.

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1. Introduction

Brandengen School is a demonstration building within the EU project «School of the Future – Towards Zero Emission with High Performance Indoor Environment». The EU project, which focus area is retrofitting, started in 2011 and will run for 5 years. The project is based on close co-operation between research institutes and industrial companies, represented by the «Advisory and Evaluation Group» involved in the planning of the demonstration buildings. This group of expert advisers works together with the building owners and their consultants to find

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solutions for considerable reduction of energy consumption, utilization of renewable energy sources, and improvement of the indoor environment. Various measures are assessed, covering the following topics: 1) Reduction of heat losses from the building envelope, and optimal handling of solar gains, 2) Heating, cooling, ventilation and lighting systems, 3) Energy supply/generation systems. The group has developed programs for measurement of energy consumption and investigation of indoor environment quality.

2. Objectives for Brandengen School

The target energy saving figure set for the school is 67 %, taking the restrictions associated with the historical buildings into account. Regarding indoor climate the objectives are to obtain satisfactory ventilation air quality and thermal conditions, avoiding cold drafts in winter and overheating in summer. The façade aesthetics should be restored as close as possible to the original historic look.

Table 1. Energy consumption and estimated savings

Total energy use	Brandengen School before retrofitting	208 kWh/m²a
	National regulation TEK 10 energy frame for new school buildings	120 kWh/m²a
	Brandengen School with planned retrofit measures. Calculated values	68 kWh/m²a
	Calculated energy savings at Brandengen School	67 %

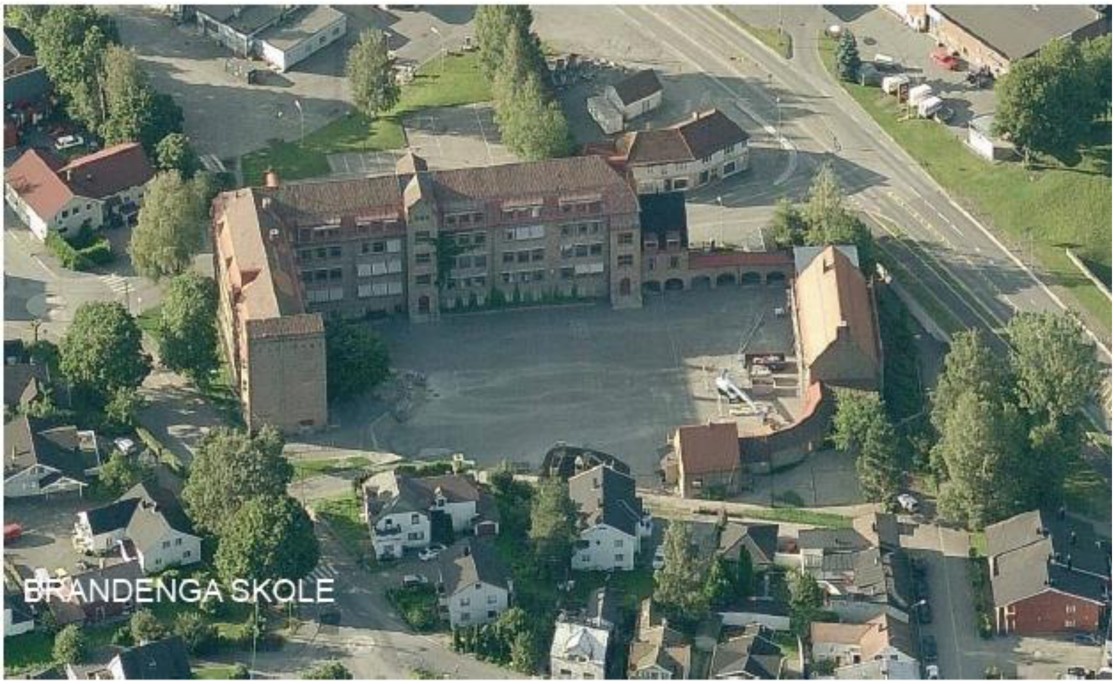

Fig. 1. Bird perspective of Brandengen School and near by surroundings, before retrofitting.

3. Renovation measures

As the ventilation and lighting systems were partly renewed in 2001–2003, the focus area of the retrofitting started in 2011, is first of all renovation of the building envelope, including replacement of windows, additional insulation in the attic and basement walls, new roof cladding, and replacement of the oil burner.

3.1. Window replacement

The windows had been replaced at different times since 1965. As the windows had caused high heating costs and not contributed to an optimal indoor climate, the municipality decided to replace all windows installed after 1965, aiming for new high performance windows, which also should pay respect to the historic aspects of the buildings' aesthetics [1]. Existing original windows from 1914 have been refurbished. Most of the original windows are located along corridors, where the indoor temperature requirements are not as strict as in classrooms. Searching for modern high performance windows the following criteria were required:

- Looking similar to the original windows from 1914
- Long life expectation
- U-value ≤ 0,8 W/m2K
- Affordable operational and maintenance costs

«Passive house windows» from the Norwegian manufacturer NorDan are now installed [2]. As these windows substantially decrease heat losses, they contribute to both better indoor thermal comfort and reduced energy bill. Thanks to the glazing's low solar energy transmittance (g-value = 27 % on south and west façades), the exterior sunscreens could be removed from the façades, in order to restore the façade aesthetics as close as possible to the original look.

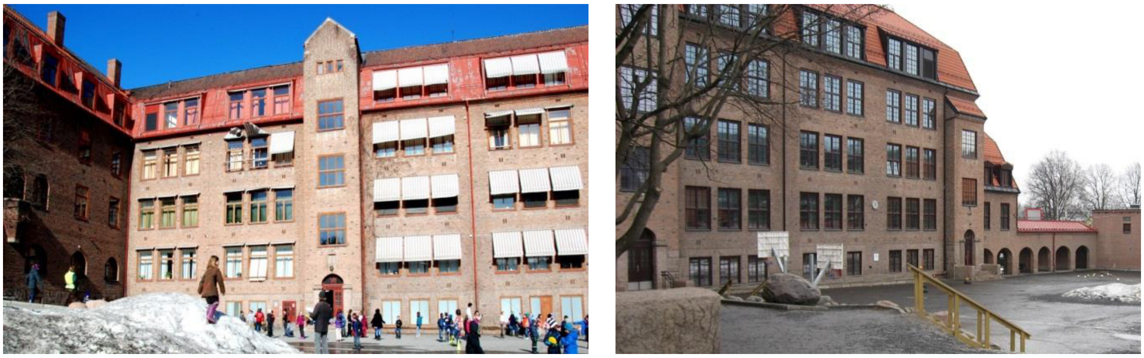

Fig. 2. (a) South façade before retrofitting; (b) South façade with new windows and roof cladding.

Table 2: «Passive house windows» from the Norwegian manufacturer NorDan.

Glazing specifications	**U-value W/m^{2}K**	**Light transmission %**	**G-value %**
Ground floor with exterior security glazing: Lam m/energi 2s VKS/Ar 6,38ES+16G+4+16G+ES6	0,53	56	35
Solar glazing on south and west façades: SKN165 m/Energi VKS/Ar 6*-14G+4+16G+ES4	0,58	48	27
Other windows have standard glazing: Energi 2s VKS/Ar 4ES+16G+4+16G+ES4	0,53	58	37

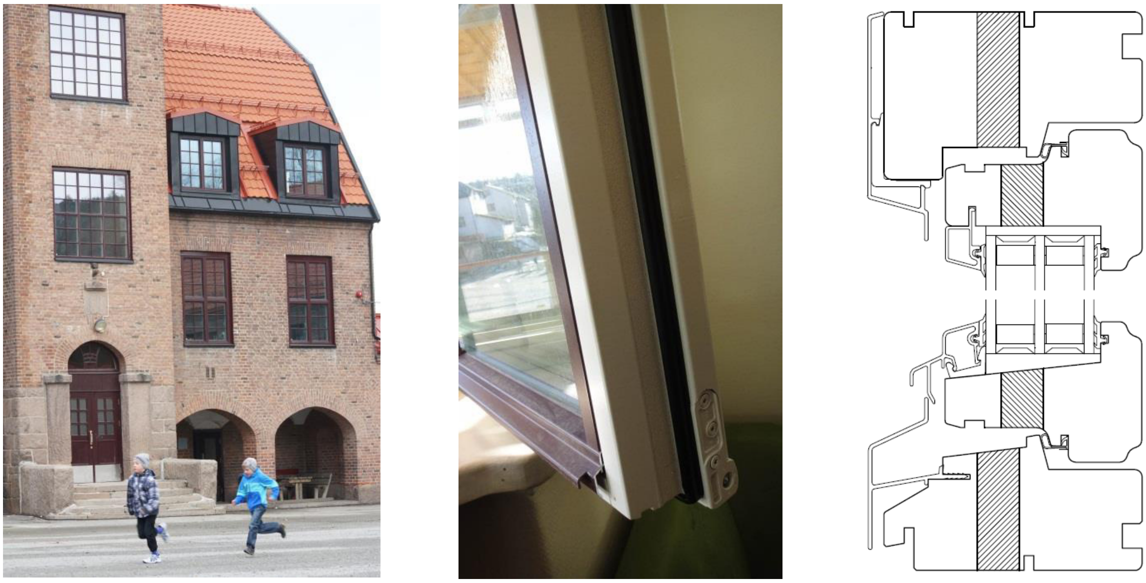

Fig. 3. (a) Façade segment showing new passive house windows from NorDan; (b) Close up photo of new window. Photos: S. Røgeberg, Mai 2012; (c) Vertical section of insulated window frames.

3.2. Insulation of the attic

Heat leakage from the roof has caused icicles in winter. Icicles have to be removed because they can harm people when falling down, and they can also harm the rain gutters if they are allowed to gain weight. Removing icicles has cost the municipality a lot in previous winters. In order to avoid heat leakage and moist problems the wall between the mansard windows, and the floor in the attic, got additional insulation, and vents were installed to provide outdoor air to flow into the attic; to cool the attic and to remove moist. In 2001–2003 a ventilation system was installed and ventilation ducts were placed in the attic. As these ducts were not so well insulated, they are now wrapped with a layer of additional insulation.

3.3. Insulation of basement walls

New drainage along the south and east basement walls was necessary to avoid moisture in the basement. The drainage ditches serve several tasks; revealing the basement walls under the ground for external insulation, filled with extruded concrete gravels the ditches provide additional insulation of the basement, and last but not least, the ditches hold collector pipes for the new heat pump. New drainage was necessary to maintain the building, and insulation will allow for a better use of the basement areas. The drainage ditches' primary function is to keep the basement dry. However; the ditches contribute to energy savings.

3.4. Increasing indoor comfort

Reducing heat leakage from the building envelope will also contribute to a higher level of thermal comfort for users. New windows with solar glazing on south and west façades will reduce heating load and glare.

3.5. Renewable energy

The policy of Drammen Municipality is phasing out oil based heating systems in their buildings. If a building is outside the network of the district heating system, the strategy is to install local heat pumps, often based on ground heat sources. Those heat pumps have to serve buildings with existing high temperature heating system.

In the autumn of 2012 the old oil burner in Brandengen School was replaced by a ground source heat pump, providing space heating and preheating of sanitary hot water. The heat pump is connected to the existing pipelines in the main building.

The old 80/60°C oil based heating is replaced with a heat pump system with heating capacity of approximately 200 kW. The heat pump utilizes ground heat from 18 energy wells drilled in the schoolyard. An exciting oil burner is modified for bio oil for peak load. This burner plus an existing electrical boiler serve as backup. The heat pump has 4 compressors and is dimensioned to 85 % of the energy demand. Under normal conditions this is enough, and the bio burner will be used only a few days when it is very cold.

The heat pump uses R134a as refrigerant, and is specially designed for variable water flow and temperatures up to 70°C. The heat pump is enhanced to benefit from low return temperatures, which often occurs in the heat system.

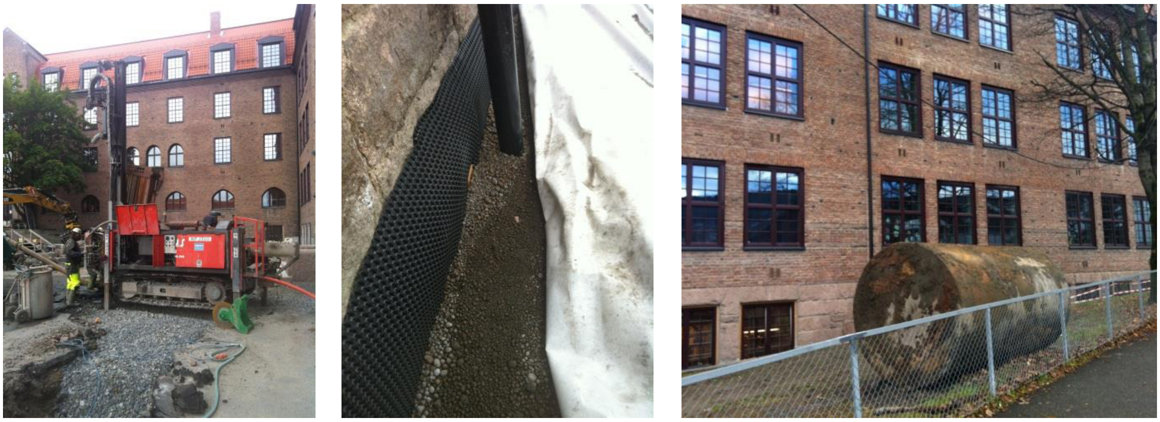

Fig. 4. (a) Digging for the ground source heat. (b) Combined digging for collector pipes, exterior insulation and drainage. (c) The oil tank on the way to destruction. Photos: G. Andersen, September 2012.

3.6. Control and monitoring

An advanced building energy management system is used to control the heat pump, heating system, ventilation, and lighting, according to demand, and to monitor the energy consumption [3].

A survey of winter conditions; questionnaire about indoor comfort and measurements of CO_2 concentrations and indoor temperature levels, were carried out before retrofitting.

4. Results so far

The façades, basement walls, attic and roof are retrofitted according to plan. The heat pump is connected to the existing pipelines in the main building.

4.1. Honorary award

The school provided the municipality a price in the award «Local Climate Initiative 2012», an award established by Zero (Zero Emission Resource Organisation – a non-governmental ideal foundation) and KS (national federation of municipalities).

Fig. 5. South façade after replacement of windows and roof cladding. Photo: S. Røgeberg, Mai 2012. Architect for the retrofitting: a-form architects / Nils Herland.

5. Further work

So far the main building is connected to the heat pump. Adjacent buildings will be connected after installing new pipelines.

5.1. Following up in the operation phase

Surveys of indoor comfort, both winter and summer conditions, will be carried out after retrofitting.

Tailored training seminars will be carried out at the end of the project, aiming to discus building operation with facility managers, and also provide teachers with training material to help to make their pupils more aware of energy efficiency and indoor environment.

Having the facility managers in mind; significant deviation between the calculated and actual measured energy consumption may appear, as the managers' knowledge and attitudes may influence directly on the energy consumption. The fact that simulations are based on standardized data for the user-controlled conditions, while managers may use the full range of the technical capacity, is relevant for a possible deviation.

Having pupils and teachers in mind; the mission is to educate and familiarize the users to establish procedures for energy conservation, in school and elsewhere. They should get to know different energy sources, get an understanding of why reduction of energy consumption is so important, and how to achieve energy savings.

6. More information

Website: http://www.school-of-the-future.eu/index.php/drammen-norway
The references can be downloaded from the website

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