Energy saving in historical school buildings: Mission impossible?

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ABSTRACT

Many Dutch cities have ambitious climate protection plans. In order to encourage both professional and private owners of monumental buildings to realize energy saving measures, municipalities aim to play an exemplary role with their own historic buildings. School buildings form a special challenge: The wish to preserve historic values in combination with the need to improve the ventilation in the class rooms and to reduce the energy loss by façades and roofs and single glazing is already extremely difficult. In addition, the financial resources for school buildings are very limited. This combination seems to result in an impossible challenge. In the city of Hilversum, the potentials for energy saving measures in six historical schools were studied. The experiences of this study were combined with the knowledge of a Dutch network where cities and the State Agency for the Cultural Heritage participate. This led to innovative technical and process related solutions for historical school buildings.

INTRODUCTION

Many cities in the Netherlands have historical and monumental buildings. The ambitious climate protection plans of the municipalities requires adjustments to these monumental buildings in order to realize energy saving measures. Quite a lot of

Dutch schools are located in a historical building and even 111 schools make use of a monumental building [1]. Monuments that house schools form a special challenge regarding the climate protection plans.

The current indoor environment of classrooms is poor. The carbon dioxide levels in the classrooms raise enormously and rise up to concentrations almost 5 times the limit value of 1200 ppm. During at least 40% of a teaching day the measured carbon dioxide levels are higher than the limit value of 1200 ppm [2]. A poor indoor environment has a negative effect on health, academic performance and vitality of students and staff [3]. So improvement of the indoor environment, by ventilation in the class rooms, is necessary in order to meet the demands of the school. In addition to the need for ventilation, the energy bills of schools are rising [4]. The need to implement energy saving measures in the building becomes larger. But to reduce the energy loss by façades and roofs and single glazing is already extremely difficult.

Schools encounter large problems planning adjustments to the building. The wish to preserve historical values creates a dilemma of listed building status versus the function of the school. 35.4 % of the Dutch schools, that collaborated in a research of the Delft University of Technology, indicate difficulties with the demands for quality preservation of the monument [1]. The possible solutions are more expensive and the available materials are limited. Thereby the requirements regarding the listed status of the monument often clash with the functional requirements of the schools.

Law and legislation are also judged as inconvenient. The procedures are extensive, slow and long. It takes time, money and acquaintance, something that schools barely have. The restrictions of the monument determine possible interventions to the building. Moreover school boards encounter problems through the social and educational developments, for instance sanitation and sizes of class rooms. The space and design of the monumental school building is not adaptable to the wishes of the school. The current legislation is not appropriate for monuments with daily living, a modern function, where flexibility is required.

The municipality has the legal mandate to ensure adequate housing for primary schools and secondary schools. The school board has the statutory duty of a good management of the school. The size of the budget and the priorities within it are highly dependent of the political will and understanding of the municipality to invest in education in it’s territory [4]. In the decentralization law is expressly chosen for the initiative on the part of the school board. The financial resources for school buildings are very limited. 64.4 % of the schools indicate to have financial problems [1]. The rebuilding of the monument is expensive because of specific and often expensive solutions. Another problem is the municipal grant for the school, which doesn´t consider the monumental status of the school building. Therefore the school doesn´t get any additional grants.

29.2 % of school boards indicate that current conditions and problems are causing the desire to leave the historical building [1]. The main reasons are the high maintenance costs of the monumental building, the described problems regarding the climate protection plans and the fact that the building itself seems more important than the quality of education, welfare and occupational health.

Despite all the troubles during the process the school boards are positive about being housed in a monument. In general the monument, because of its character and appearance, is seen as more value to the school, street and neighborhood. The listed status of the building is the symbol of the school and enhances the appearance of the school, neighborhood and city district [1].

GOALS AND RESEARCH QUESTIONS

The aim of the study is twofold: collecting the identified problems and issues and targeted research on a number of practical examples. The research question is: What are the practical possibilities of energy saving in historical school buildings?

To answer this question, the results of a research based on experiences in six schools with historical value in Hilversum were used as well as the results of a so called 'learning meeting' of a Dutch National network focused on a sustainable approach of buildings with a historical value. In this article these sources are described and compared with each other.

CASE STUDIES

Source 1: Six case studies in Hilversum – looking for common situations

In 2009-2010 the research 'Sustainable Preservation of Historical School buildings – Six Case studies' [5] was conducted by NIBE (Dutch Institute for Buildingbiology and Ecology), commissioned by the municipality of Hilversum.

The background. In the city of Hilversum 19 historical school buildings are still in use and listed as monuments, 8 of them are national monuments and 11 are listed as local monuments, many of them designed by architect Willem Marinus Dudok.

No other Dutch city is so formed by the hand of one architect. His most famous building is the town hall, but Dudok also designed schools, homes and other buildings in Hilversum and surroundings. In 1915 he became the director of public works for the municipality of Hilversum, which was expanding from a village to a city in this period. Dudok was responsible for the construction of streets and plantations, for the management of trams, electricity, gas and water but also for the design of public buildings and homes. When he finally became city architect in 1928, he concentrated entirely to architecture. And even after his retirement, in 1954, he still built a lot in Hilversum. Thus Dudok left his marks in this city for more than 50 years. In his work he combined different Dutch architectural trends, resulting in his own special 'Dudok-style'. In his style elements of the Amsterdamse School, the School of Berlage, De Stijl etc can be found. One of the characteristics of his style are the high chimneys, breaking the horizontal planes. Another characteristic are the beautiful colors he used in many of his buildings. In Hilversum he frequently used the colors yellow and blue which are the colors of the cities' blazon. [6]

The municipality of Hilversum is very careful with this special legacy and is proud of the high restoration standards that are achieved in recent restorations, e.g. the restoration of the Town Hall and Zonnestraal. Indeed Hilversum fulfills a frontrunners position in the Netherlands.

Figure 1. The pictures above show two famous buildings in Hilversum: On the left side the sanatorium 'Zonnestraal' designed by architect Duiker and on the right the Town Hall designed by architect Dudok.[1]

On the other hand, according to her Climate Plan the municipality of Hilversum aims to realize an energy saving of 3 % per year in her own buildings and wants to produce or buy at least 70 % green energy [7]. This means that the municipality also has to manage her own building stock in a sustainable way. The many historical buildings form a special challenge, because a careful balancing between the sustainability ambitions and the historical values has to be found. The above mentioned ambition is also applied for schools, even though schools have a special position: As in most other Dutch cities there are shared responsibilities between the municipality and the school boards. The municipality is owner of the school buildings and is therefore responsible for the structural measures, like restorations and expansions. In recent years the school boards were given more and more responsibilities. Today it is the school board who is responsible for the installations. The school boards also have to pay the energy bill and, if necessary, the additional costs for green energy.

Reason for the research 'Sustainable Preservation of Historical School buildings – Six Case studies' was the high energy consumption in the historical school buildings and thus the wish to identify possibilities for energy saving, without losing historical values. Furthermore the municipality was worried about the poor indoor climate due to inadequate ventilation in the classrooms. The latter even led to the question if the historical school buildings are still suitable for teaching children. Of course, reducing the number of children per classroom would improve the indoor climate but, as for the majority of schools in the Netherlands, this is not a realistic solution – and even then, improvement of the ventilation would still be necessary.

As the case studies, all originally had the function of 'school' the following questions arise:

- Were the demands and wishes for school buildings in the past lower than our current needs and wishes?

[1] The picture of Zonnestraal is made by Michiel Haas, the picture of the Town Hall is made by Birgit Dulski.

- Did later interventions lead to a better indoor climate than in the original situation?

- Is the energy consumptions of the historical schools in Hilversum higher than the consumptions of schools in other communities?

- Is the indoor climate in schools in other communities better than in the historical schools in Hilversum?

- How can the indoor climate be improved with preservation of the historical values?

The cases. In close consultation with the municipality of Hilversum six historical school buildings were chosen as case studies.[2] Four schools are built in the period of Dudok, one is built before and one after his period.

Figure 2. Photos of the Minckelersschool.

The *'Minckelersschool'* is composed of two originally separated buildings. They became connected by a new element in the 1980's. This new element is realized in the same style as the older buildings. The main building was realized in 1927 and is designed by architect Dudok. It houses the classes 3-8 of the primary school. The *Minckelersschool* is a special example for the architecture of this period because of it's historical and architectural values, it's special ensemble and it's integrity.

Figure 3. Photo of the Nelly Bodenheim school.

The *'Nelly Bodenheim'* school belongs to the ensemble of the *'Minckelersschool'* and houses the classes 1-2. This building was realized in 1929 and is also designed by Dudok.

[2] The case studies in Hilversum were visited by Birgit Dulski and Evert Jan Nusselder, Bureau Monumentenzorg. All the pictures of the case studies in Hilversum are made by Evert Jan Nusselder.

Picture 4. Photos of the Violenschool International.

The *'Violenschool International'* is built in 1919-1920, designed bij Dudok, too. Today, also a kindergarden uses parts of the building. The structure of the building and many details are still original. In 2001 the school is carefully renovated by an experienced restoration architect. Preservation of historical values got high priority during the restoration.

Figure 5. Photos of the Alberdingk Thijm College.

The *'Alberdingk Thijm College'* was built in 1937-1938, designed by architect Nicolaas Andriessen. Today it houses an international primary and secondary school. The style of the original part is 'expressionism' and it is obvious that there are influences of Dudok and the early designs of Frank Lloyd Wright. In the 1950's a new part is added to the original school building, thus creating a protected schoolyard.

Figure 6. Photo of the Godelindeschool

The *'Godelindeschool'* is a primary school, built in 1904. It is the only case study that is built before the period of Dudok. The building is designed by architect Hanrath, who designed many mansions in Hilversum and the surrounding of the city. In 1919 and in 1928 his son designed two new parts, in the same style as the original school. Characteristical elements for Hanraths architecture are the use of bricks, the valiant

wooden windowframes, the large roof-overhang, the oriels, and the glass partitions or rod-glass in the windows.

Figure 7. Photo of the 'De Wissel'

The school *'De Wissel'* houses a practical school for children with learning disabilities. Built in 1960-1961 it is the only case study that is realized after the period of Dudok, designed by architect Joustra. The building has a concrete structure with columnas on the ground floor. On the first and second floor walls are situated perpendicular to the long façades.

In all the case studies originally single glazing was used, and the façades, roofs and ground floors were all uninsulated. The energy loss in the winter therefore was high and the temperature in the classrooms low. In the times these buildings were realized this was accepted as 'normal' situation and children and teachers were adapted to the lower temperatures by wearing warmer clothes in the winter. All the case studies were ventilated with natural ventilation: Windows were hand opened, in order to get enough fresh air in the classrooms. In addition, for each classroom a volume of at least 4 m^3 volume per person was required. This requirement was often met by realizing 1 m^2 surface for each person and a height of about 4 m.

Today our demands and wishes for the indoor climate in schools (and in buildings in general) are much higher. For example we expect the same temperature in the class rooms all over the year. Three of the case studies were visited in December 2009: It was striking that even in the middle of the winter, many children wore T-Shirts with short sleeves. The higher temperatures in the class rooms were achieved by setting the radiators on a higher temperature. Since the radiators usually are situated at the façades, below the windows, the results were condensation on the windows and a bad indoor climate. The temperature in the surrounding of places on the opposite of the façade is too low, while the children who are sitting close to the radiators complain about heat. Furthermore the energy loss is high due to the uninsulated façades.

Good day lighting is also part of a healthy indoor climate. But today, direct daylight can lead to reflections on the digital school boards. For some of the case studies this is even the reason to use solar shadings.

Ventilation in class rooms: current practice and requirements. The class rooms of all the case studies are still ventilated by natural ventilation. In some of the schools there are special rooms, like rooms for art education or a library, in which mechanical air extraction is installed – but these are exceptions. In the washrooms and toilets however most schools have installed a mechanical ventilation system. Not all the windows, that originally had a ventilation function in the class rooms, are still used: In some class rooms different windows cannot be opened any more and on the

corridors the researchers found ‘forgotten’ windows. This situation also contributes to the insufficient ventilation. In the class rooms of all case studies suspended ceilings were applied, which hide pipes and cables and in some schools the fixation of the digital school boards, too. Due to the suspended ceilings the air volume in the class rooms is reduced and in some cases historical ventilation channels are interrupted. Furthermore, today there are more children in the class rooms than in the past. The original requirement of 4 m^3 air volume per person is thus not reached any more.

The current ventilation requirements are complex in the Netherlands. In the national building regulation, the ‘Bouwbesluit’, ventilation requirements are defined in relation to the occupancy. A difference is made in three degrees of occupancy:

- B1: $\geq$ 0,8 m^2 usable area per person
- B2: $\geq$ 2 m^2 usable area per person
- B3: $\geq$ 5 m^2 usable area per person

Table 1. Ventilation requirements for buildings with an educational function and for office buildings according to the Dutch building regulations (‘Bouwbesluit’).

Degree of occupancy	**New buildings: B1**	**New buildings: B2**	**New buildings: B3**	**Renovations**	**New buildings: at least dm^3/s**
Educational function, minimum ventilation (dm^3/s per m^2)	8,3	3,5	1,4	1,1	10
Office buildings, minimum ventilation (dm^3/s per m^2)	1,3	1,3	1,3	1,0	7

Table 1 may suggest that the ventilation requirements for school buildings are higher than the requirements for office buildings. This does not correspond with the practice: In office buildings an average of 20 m^2 per person is usual in the Netherlands. An occupancy belonging to degree B1 does not occur in offices, while schools always belong to degree B1. The requirement of 8,3 $dm^3/s/m^2$ for a new built school is not ambitious. The indoor climate of a class room which meets this requirement is bad compared to a new built office. For the renovation of older schools the requirement of 1,1 dm^3/m^2 is significantly lower.

In addition to the requirements of the ‘Bouwbesluit’ there are minimum standards for the ventilation in buildings defined in the national norms, eg the NEN 13779. According to this norm the minimum ventilation should result in 6, 9 and 15 liter/second/person, depending on the function of the rooms. The GGD (Gemeentelijke en Gemeenschappelijk Gezondheidsdienst) recommended in 2006 in

his research ‘Toetswaarden voor ventilatie in scholen en kindercentra’ 25 liter/second/person for class rooms in school buildings [8]. This value corresponds to 90 m^3/hour/person en with a delta [CO_2] of 250 ppm. According to the NEN 13770 the delta [CO_2] is the $[CO_2]_{inside} - [CO_2]_{outside}$. It is used to determine the CO_2-level because the $[CO_2]_{outside}$ depends of the location and can vary on different moments. The researchers of the GGD listed the recommended minimum values and classified them.

Tabel 2. Minimum values and classification according to the in 2006 by GGD Nederland conducted research ‘Toetswaarden voor ventilatie in scholen en kindercentra’ [8].

Classification	**CO2-level inside-outside, 98-percentage**	**Fresh air flow per person**	
	parts per million (ppm)	liter per second	m^3 per hour
0. Very good	< 250	>25	>90
I. Good	250-400	15-25	54-90
II. Moderable	400-600	10-15	36-54
III. Insufficient	600-1.000	6-10	22-36
IV. Bad	>1.000	<6	<22

In office buildings a minimum standard of 800 ppm is usual in the Netherlands. The initiative ‘Sustainable Schools’ which started in 2009 recommends a minimum of 1.200 ppm for classrooms [9]. These example illustrates the complexity: While ‘Sustainable Schools’ consider a school as a good practice if a CO_2-level of 1.200 ppm is reached, the researchers of GGD Nederland consider the same value as ‘bad’.

The situation in historical schools here is illustrated with the example of the Minckelersschool: The available CO_2 measurements in one of the class rooms show that during peak times a CO_2-$level_{inside-outside}$ of about 2.000-2.500 ppm is reached. As the CO_2-level is depending of the number of children in the class room the values vary strongly per day and moment. The average CO_2-level fluctuates around the 1.400 ppm [10]. Even though the different minimum standards vary, it is obvious that the class room does not meet the recommendations of experts. Based on these case studies in Hilversum, a list of ‘common situations’ was made by NIBE. For each situation a range of possible solutions is worked out. To improve the indoor climate in the class rooms of the Minckelersschool a mechanical ventilation system with heat recovery is suggested. Of course, the possibilities for such systems depend on the situation and are not possible for all historical schools. For the Minckelersschool it was planned to realize a new ventilation unit on the attic. In a non-monumental school new pipes could be realized, penetrating the roof, in order to make the necessary air flow possible. Due to the high historical values of the roof this solution is not acceptable for the Minckelersschool, but there is another option: One of the characteristic elements of the Minckelersschool is the large tower, which has openings in all four façades. These existing openings can be (re-)used for the air flow of a modern and energy saving mechanical ventilation system with heat recovery and CO_2 sensors. New pipes on the attic can distribute the fresh air to the class rooms.

The used air can be transported by the same way from the class rooms to the opening in the tower. Thus the already available potentials can be used on a creative manner.

Energysaving: opportunities and restrictions. The energy consumption of historical schools is high in relation to recently built schools. This is mainly caused by the uninsulated façades, roofs and ground floors, the single glazing in the windows, old installations and/or not adequate use of installations. For the six case studies possible solutions for energy savings were worked out. If all recommended measures are realized, a reduction of 33-35 % is expected. The Minckelersschool and the Alberdingk Thijm College (ATC) achieve the lowest reduction (both 33 %), but for completely different reasons: At the ATC there are very few possibilities for interventions without loosing historical values. In the Minckelersschool a new mechanical ventilation system is recommended which will cause additional energy consumption. This additional consumption of electricity will partly be compensated by a reduction of thermal energy due to the heat recovery of the ventilation in combination with insulating measures and more effective radiators. This combination of measures will not only save energy but also will significantly improve the indoor climate.

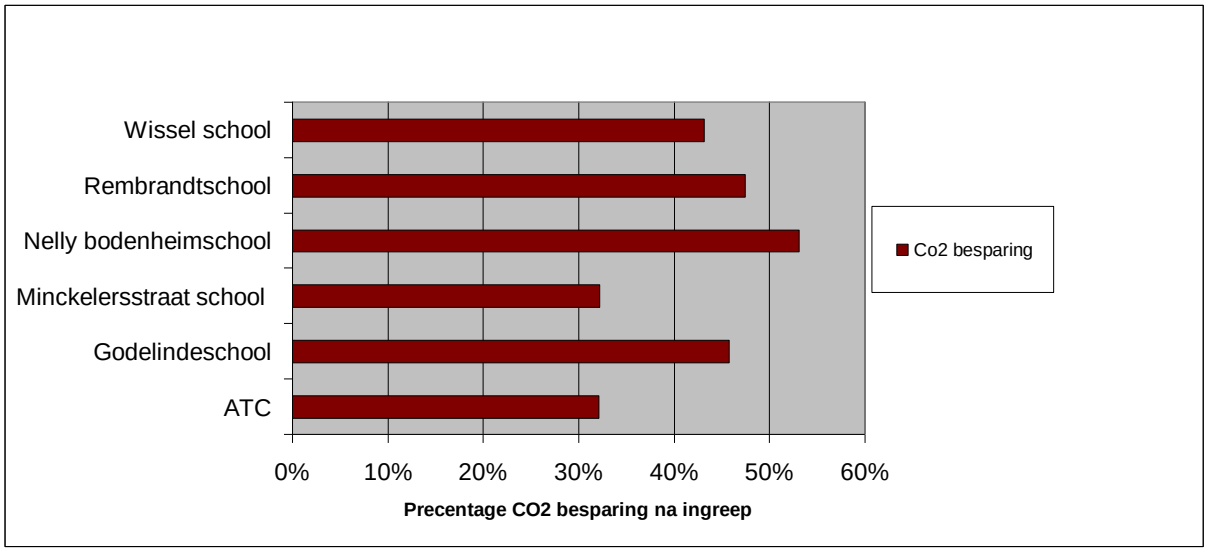

Figure 8. The expected energy savings for the six case studies if all recommended measures are realized.

Also the possibilities for energy saving measures are illustrated at the example of the Minckelersschool: The researchers recommended a mechanical ventilation system with heat recovery. This system asks for a reducing of air leaks and energy loss in the building, too. As the attic of the Minckelersschool is not used for educational functions it is not necessary to insulate the roof. The new pipes should be insulated and the floor of the attic, as well. Both measures do not lead to a loose of historical values. On the infrared photos which are available for the Minckelersschool it is shown that energy losses occur, above all, at the windows (about 80 %). The brick façade is not the big problem [11]. In order to reach a more even temperature in all parts of the class rooms and to reduce the energy loss it is – in some situations - possible to place second windows behind the original windows. Together with the

new glazing the air filled space will lead to a significant improvement of the insulation value. However, it should still be possible to open the windows, even if this is not strictly necessary if a mechanical ventilation system is installed. For the Minckelersschool it is eventually even possible to choose for double glazing windows behind the original ones, but as this could lead to interfering reflections, the choice must be made very carefully. Some of the wooden frames and the handles are not original and therefore the current glazing could be replaced by new insulating glazing, but it has to be guaranteed that the original characteristics will be unchanged, or even restored. Replacing the window frames is not a realistic option, as they also have a constructive function. Finally, it was recommended to realize 'test-windows' in one class room. The test situation allows to monitor the energy savings and the comfort improvements and an expert for the preservation of cultural heritage should decide which solutions would be the best one.

The radiators in the class rooms of the Minckelersschool are not original but were placed in the 1960's. They do not have historical values and can be replaced by new and more effective ones. In addition a reflecting film can be placed on the wall behind the radiators in order to reduce the energy loss due to the uninsulated façades.

Common situations. For the six case studies in Hilversum NIBE developed customized solutions, but also looked for 'common situations' and possible solutions which would improve the indoor climate and reduce the energy consumption. These 'common situations' are:

- Uninsulated façades and historical windows with single glazing lead to discomfort and energy loss. Insulation will have negative consequences for the building physics and/or the historical values of the building.

- The ground floor is mostly uninsulated, too, again leading to discomfort (cold feet) and energy loss. Insulation is difficult due to pipes and wires.

- The CO_2-level in class rooms is too high. Ventilation is only possible by opening windows, leading to energy loss and discomfort.

- The release of the heating is ineffective. Radiators are situated close to the (uninsulated) façades and are frequently wainscoted. Often the heating temperature is too high, resulting in discomfort and high energy consumption.

- All rooms are heated, even staircases, corridors, entrance halls etc, leading to a high energy consumption.

- Historical (pitched) roofs do not allow interventions. Thus there are no possibilities for new drain pipes (e.g. for a new ventilation system), skylights (e.g. necessary for new classrooms in the attic), insulation and/or solar energy.

- Many schools don't have a concierge, which means that teachers have to regulate and maintain the installations. In most cases they don't have the necessary knowledge and there is also a lack of time. This leads to ineffective installation systems and high energy consumption.

- In many schools the lights are always on, again leading to a high energy consumption.

- Suspended ceilings in the class rooms hide cables and pipes, but disturb the visual impression and reduce the air volume. In some cases historical ventilation channels are interrupted. Thus the suspended ceilings also contribute to the poor indoor climate.

For these 'common situations' a range of possible solutions is worked out by NIBE. Three of the totally seven examples are presented below.

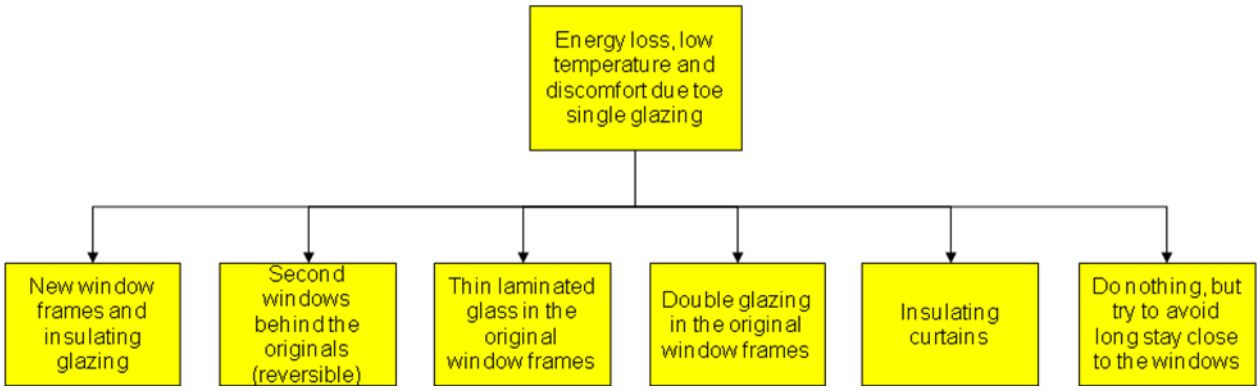

Figure 9: Example for a 'common situation': a range of solutions for energy loss and discomfort caused by single glazing in windows.

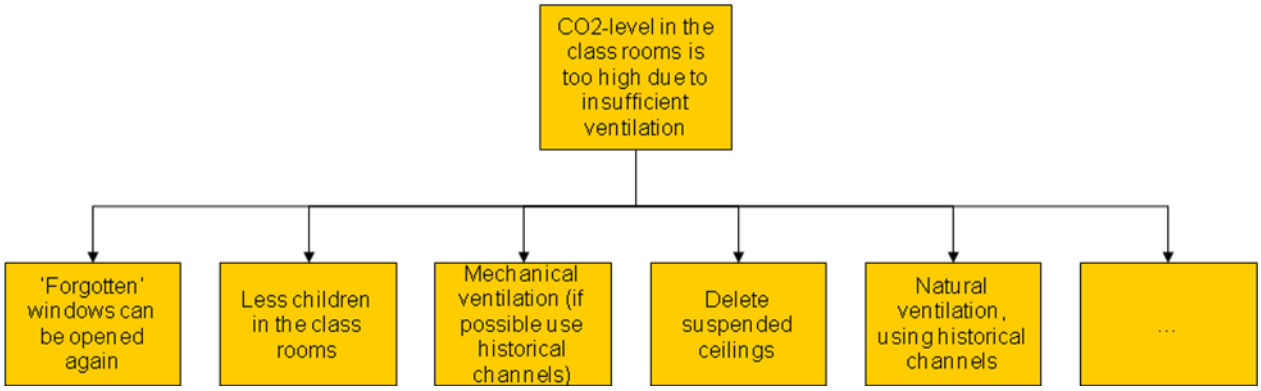

Figure 10: Example for a 'common situation': a range of solutions for high CO_2-levels in class rooms caused by insufficient ventilation.

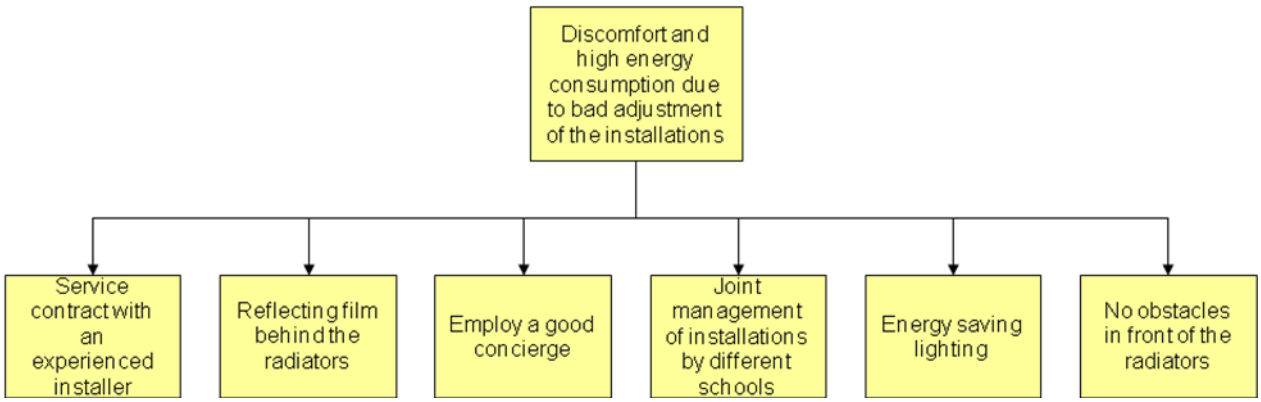

Figure 11: Example for a 'common situation': a range of solutions for discomfort and high energy consumption caused by inefficient installations.

Suggestions for process related measures. Besides the 'common situations' and the possible solutions the research in Hilversum also led to suggestions for process related measures. For example it was recommended to establish a peer review team which first aims to realize the easily achievable and quickly recoverable measures. This first step will already result in a lower energy bill for the school. If these savings are invested in a local revolving funds, more energy saving measures can be realized in the same school in the future or in other schools in the same city. Thus the limited financial resources can be used effectively.

The case studies in Hilversum show that a smart and creative combination of technical solutions and process related measures is necessary. Otherwise the technical solutions cannot be brought into practice. Therefore it was all the more welcome that the members of a 'national network', initiated by the Center for Sustainability of the Nyenrode Business University, paid special attention to this item.

Source 2: National Network with 'Learning Meetings'

In September 2010 the Center for Sustainability (CfS) of the Nyenrode Business University launched a national network in which local, regional and national governments - as cultural historic and sustainability parties – participate to achieve more knowledge about a sustainable approach of buildings with a historical value. At the moment seven municipalities (Arnhem, Delft, Den Haag, Haarlem, Hilversum, Nijmegen, Utrecht) one regional government (Provincie Drenthe) and the State Agency for the Cultural Heritage participate in the national network, which will (at least) be active until September 2013. Together the network participants conduct research that is done by the CfS. They exchange experiences and discuss the results of the researches in order to implement these in their local (climate) strategy. Regularly the network invites professional partners of the construction chain for 'learning meetings'. With the 'learning meetings' the members of the network aim to identify new forms of cooperation, involving external partners previously in the process. The main questions during the meetings are the following:

- Can owners of a historic building make better use of the experiences of companies in the construction chain by working together in a early phase of the project and in another way? / Will an early market consultation lead to benefits for the conductors of restoration projects?

- Which are the demands for the process? / What hurdles must be overcome?

In January 2011 these questions were investigated for the example of the Cathedral Choir School in Utrecht.[3] The members of the national network, most of them working for municipalities and either experts for sustainability or experts for the preservation of cultural heritage, have chosen for a school building after the experiences of the research project in the city of Hilversum were discussed in the national network in September 2010. It was evident that the possibilities for energy saving in historical school buildings are a hot item in the other Dutch cities, too. Different members of the network considered energy saving in historical school buildings as a 'mission impossible' but nevertheless the energy saving measures in this type of buildings were considered to be necessary.

The background. In the Dutch situation restoration projects are often tendered in a traditional way. In new building projects and common renovations there is more experimented with with new forms of cooperation, such as

- Total Costs of Ownership (TCO), which means that the developer is also responsible for running costs of the building for a certain period (eg for 20 years).

- The 'Bouwteam', which means that the owner of the building, the architect, the builder, the consultants etc work close together from the start of the project.

- Design & Construct, which means that design and construction are realized by the same company.

Many professionals in the Netherlands expect that the creativity and the practical knowledge of all concerned parties can better be used in these new forms of cooperation. Most members of the network are convinced that these new forms of cooperation are worthwhile for buildings with historical values, too.

These new forms of cooperation, like any other form of early market consultation, demand another process, in which the owner of the building and the municipality play other roles than usual. For example it is not the owner / the municipality who exactly defines the specifications and requirements, parts of these task are outsourced to the market – assuming that the participating companies will propose new, creative and smart solutions. Also the assessment of the proposed solutions asks for another interpretation. Not only the lowest price is decisive but different criterions, that are considered to be important, should be taken into account. Examples for these criterions are – beside the investment costs – the running costs and the appreciation of sustainability performances. The new forms of cooperation also ask for new organisation forms within the municipalities: In the current situation in many Dutch municipalities different divisions are responsible for investment costs and the running costs, which causes different (mostly contradictory) interests.

[3] During the 'learning meeting' in January 2011 this contradiction was discussed with three external partners: Maarten Fritz, director of Bureau Fritz / restoration architect, Marco San Giorgi, director of Jurriëns Aannemingsbedrijf / restoration builder and Michiel Haas, director of NIBE and professor at the Technical University of Delft.

To describe the different stages of the building process regarding schools with historical values the CfS-researchers defined six phases which were discussed during the 'learning meeting':

- Phase 1: development of the strategy,
- Phase 2: specification / requirements,
- Phase 3: selection,
- Phase 4: tender,
- Phase 5: realization,
- Phase 6: aftercare.

In projects that are tendered traditionally the market parties get involved after the municipality / the owner of the building has completed the first two phases (development of the strategy and specifications / requirements). In projects which are realized with early market consultations the involved companies are invited to develop and share ideas from the beginning in phase 1. The municipality / the owner only define a very limited framework.

The case. The Cathedral Choir School is a special school: children in the age of 9-12 years follow not only the regular education programme, but in addition they get extra singing lessons and they all sing in a choir. The school is located in a historic typical Dutch mansion next to a canal in the inner center of Utrecht and the school building is listed as a national monument. In the current situation not only the school building itself, but also the neighboring buildings, are owned by NIKK (Nederlands Instituut Katholieke Kerkmuziek). The school is located at Plompetorengracht No. 5, the two other buildings, No. 1 and 3, are rented. The building at No. 5 is since 1959 in use as a school. The photos below show the front façade of the Cathedral Choir School in the current situation.

Figure 12. The photos above show the Cathedral Choir School in Utrecht. [4]

Since the 16th century the building which now houses the school formed together with the neighbor house, No. 7, a large mansion, where rich families lived. In the 17th century in both buildings, No. 5 and 7, identical windows were made in the forefront. It was then, too, that all over the house a new continuous roof was made. This created a very broad and patrician mansion. Probably the façade was not yet

[4] The photos of the Cathedral Choir School are made by Birgit Dulski.

plastered and there were no attic windows. Furthermore it seems that the right part of the back house No. 5 was replaced by a new one in the 17th century. The floors of both buildings were adapted to each other, but the floor above the cellar remained unchanged. During the same period, around 1632, the house No. 3, in which since 1925 the Kerkmuziekschool (Church Music School) was located, was newly built. In 1663 a new street was made at the back of the houses, so that coach houses could be built there. One of the coach houses is now used as a bicycle parking and entrance for the pupils of the Cathedral Choir School. In 1699 the residents of No. 3 bought the house No. 1, resulting in a house of 8 windows wide – like the neighbors of No. 5-7. Half a century later, when they also bought the gatehouse at the right side, the mansion got even wider. The nine windows wide façade was given a beautiful Louis XV-party entrance with balcony. The owners of No. 5-7 did not want to perform less and were also making a new entrance, but somewhat simpler, without stone staircase. Furthermore, the front slightly raised and small attic windows were installed. In 1882 the house mansion was divided and No.7 almost always kept a residential function. No. 5 remained a residential building until 1939. Since 1959 the building is in use as a school.

Besides the music education another unusual fact is that many gifted children visit the Cathedral Choir School. This situation requires a customized education, with lots of individual coaching. There are about 24 children in one class, which is less than usual in Dutch primary schools. It is also because of the customized education that there are no digital school boards in the classrooms. Compared to other primary schools the time that children work in the corridors is very limited – the entrance, staircases and corridors therefore do not to be heated.

In 2008-2009 the school building was restored on the outside. In the current situation the children use the entrance in the basement, located at the rear. In the basement there is the wardrobe for the children and a small library. Luckily there are no moisture problems in the basement. At ground level an expansion is realized where the director's office is situated. At ground level and on the first floor there are three classrooms and additional rooms for the music lessons. The class rooms still are high rooms, without the in primary school often applied false ceilings. Despite the high windows it is necessary to turn the lights on during the day. The building is not insulated. The windows have wooden frames and are all fitted with single glazing, except the windows in the concert hall which got second windows behind the original ones. There also are many air leaks. Nevertheless, the owner thinks about installing a mechanical ventilation system with heat recovery in order to improve the indoor climate. The school needs more rooms for educational functions and therefore wants to realize changes in the rooms on the second floor, eg remove some interior walls. In order to make the attic suitable for educational functions interventions in the construction of the roof are inevitable and new skylights are needed to meet the requirements for daylighting. The roof is not insulated, either. Like the neighbor houses the school makes use of the district heating system. The installation is located in the basement of the neighboring building.

Questions and needs of the users and owners.

1. Like in many other historical schools the running costs are high due to the high energy consumption. NIKK and the director of the school therefore are looking for solutions to reduce the energy consumption.

2. At the same time parents of the pupils complain about the poor indoor climate, especially about the high CO_2 levels due to inadequate ventilation in the classrooms.
3. Finally, the school needs more space, partly due to changes in the educational concept and the wish for more customized education. The rooms on the second floor and attic are now used for storage and archiving. How could these rooms become suitable for educational functions?
4. As the school, like almost all Dutch schools, only has a limited budget, there must be searched for creative financing models.

New organization of the process. The external guests of the 'learning meeting' (an architect and a constructor specialized in buildings with historical values) were asked to describe their visions for an early market consultation for the restoration of the Cathedral Choir School in relation to the new forms of cooperation. Thus the emphasis of the 'learning meeting' was not on the technical solutions but on non-technical measures and an innovative organization of the process. This resulted in the following suggestions:

- It was suggested that during the design process the building contractor should be involved, in order to make an intensive analyses of the planned interventions and the financial and visual consequences. This analyses is expected to need 2-3 weeks but the early integration of practical knowledge and experience of the contractor will lead to a faster and less disturbed process. This is a new organization of the process, because in most cases the contractor is involved when the design process is finished.

- Also it was suggested that experts for the preservation of cultural heritage should be involved in a early phase. If the experts are involved in the design process it may be expected that the permission for the interventions can be given without problems. This is already brought into practice in different projects, but still there are many projects where the owners invest money and time in the design process without consultation of the expert for the preservation of cultural heritage, which finally often requires changes, resulting in additional costs and a longer process – both could be avoided by an early consultation.

- It was recommended to look for new partnerships. One example are covenants where different partners (eg the owner, architect, contractor, municipality, financial expert) make appointments about the results in the first phase of the project. This appointments should concern the preservation of historical values, the energy saving ambitions, the improvement of the indoor climate, the financial investments and the consequences for the running costs. In the Netherland there is a long tradition with convenants between municipalities and market parties to make appointments about sustainability ambitions. Also different housing corporations try out new partnerships based on covenants. For private owners, like the school boards, this is a new idea. The success of the covenants is based on the expertise of all participants and – of course – the trust in each other.

- Another form of a new partnership is the organization for owners of historical building in the same street or surrounding, or for owners of historical buildings with the same questions (e.g. buildings from the same period or buildings with the same function). Together they can exchange experiences and can commission research to identify common situations and possible solutions, as shown for the case studies in Hilversum. The first step to realize new partnerships between different owners of historical buildings is to find other owners with the same interests.

- Also the role of the architect was discussed. In former times the architect had a central position: he was responsible for the whole process and the owner of the building trusted him completely. Today, many projects are realized by whole teams and the architect is no more than a member of the team. For highly complex projects the latter is the most practicable solution and integrating the suggestions above can lead to a faster process and less investments, which are shared interests of all involved parties. But for less complex projects, maybe it is the best solution to restore the position of the architect.

- Finally the idea raised to establish a fund for the renovation of historical school buildings. The (national) government should once invest in the fund, so that energy saving measures in historic school buildings can be realized. But the school boards should be obliged to pay the same costs for the energy supply as before. Thus the difference between the costs paid by the school boards and the real – lower – energy costs can be invested in the funds again. The result should be a revolving fund, that offers the possibility to realize more and more energy saving measures in historical school buildings.

COMPARISON OF THE RESULTS OF THE TWO SOURCES

It is easy to conclude that historical school buildings are not suitable for teaching children any more because of the poor indoor climate. The case studies in Hilversum and the results of the discussion during the 'learning meeting' of the network regarding the Cathedral Choir School in Utrecht show that ventilation is indeed a big problem but that there is a strong need for several reasons to take measure tol improve the ventilation in class rooms. There are practical ways to improve the indoor climate. Every situation asks for different solutions. However: In most cases these measures will not result in the situation that the indoor climate meets the desirable CO_2-levels (e.g. < 800 ppm) in the class rooms at all times. Determining the turning point when a school can no longer be used for an educational function remains difficult. One of the results of the research in Hilversum is that the conversion to office buildings would lead to an even higher energy consumption, unless a vary careful integration of the necessary interventions could be guaranteed. Also conversion to another function will in most cases result in higher energy consumption and the need to realize many interventions. Only very careful integrations will ensure the preservation of the historical buildings. Moreover, this also applies for maintaining the current function of school: The comfort demands and the need for interventions are expected to increase. Based on the research in Hilversum as well as on the network discussions it can be concluded that historical schools are still suitable for their educational function. For each school appropriate customized solutions have to be found and there seem to be sufficient possibilities.

The energy consumption of historical school buildings is much higher than in recently built schools. For the six case studies in Hilversum different ‘common situations’ were found and possible solutions were described. Nevertheless, the sustainable preservation of cultural heritage however, as was concluded during the ‘learning meeting’, always means looking for appropriate customized solutions. Thus the inventory of ‘common situations’ cannot result in general measures which are suitable for all historical school buildings but actually leads to a broad range of possible solutions. For each school building the most appropriate measures have to be found and the inventory of common situations and the range of solutions can help to find them. All described school buildings in Hilversum and Utrecht offered possibilities to improve the indoor climate and to reduce the energy consumption. If all recommended measures are implemented the energy consumption is expected to be reduced by 30-35% in the case studies in Hilversum. During the ‘learning meeting’of the national network, initiated by the Center for Sustainability of the Nyenrode Business University, again the idea of a revolving fund raised, but now on a national level. A revolving fund can seems to be an effective way to finance energy saving measures.

The Hilversum research leads to the conclusion that savings due to the lower energy bill costs can be invested in a revolving fund, so that more energy saving measures in schools can be realized in the future.

CONCLUSIONS

The research question of this article was: What are the practical possibilities of energy saving in historical school buildings? Based on the case studies in Hilversum and the experiences of the national network the following answers can be given:

- There are several innovative technical and process related solutions for historical school buildings, which can be used in different Dutch cities. Based on the case studies in Hilversum, a list of ‘common situations’ was made by NIBE. For each situation a range of possible solutions is worked out. An example for a ‘common situation’ is the high energy loss, the low temperature and discomfort in the class rooms due to single glazing. The possible solutions vary and depend on the existing situation. Replacing the existing windows by new window frames and new insulating glazing is only acceptable if the existing windows don’t have historical values. Another option is the preservation of the existing (maybe historical) windows but put a second window behind the original one. This measure preferably is realized on a reversible way. In cases that the window frames have historical values but the glass doesn’t it is often possible to place special thin laminated glass in the existing frames. As the costs of this special glass are high this measure is not always possible. If there is no financial budget for special glass, and also in cases that the original glass is still there, the best solution may be a heavy insulating curtain. Finally, in some cases no interventions are possible and thus the best solution is to use the room in a suitable way, which means to avoid a long stay close to the windows (Figure 9). Another example for a ‘common situation’ is the high CO2-level in the class rooms due to insufficient ventilation. Again there are different solutions possible, like the example of the Minckelersschool shows (as described in ‘*Ventilation in class rooms: current practice and requirements*’ and showed in Figure 10). The main conclusion of

this article is that energy saving in historical buildings demands customization for each school. For that reason the most appropriate solution can, dependent on the specific circumstances, be found in this range of solutions.

- In order to reduce the high energy consumptions of historical school buildings and to improve the indoor climate in the classrooms close cooperation between different departments of the municipality and school boards is necessary. This cooperation can for example be based on partnerships between owners of historical buildings who share the same interest, or of partnerships between owners and market parties. Also it seems promising to involve experts in an early phase of the project in order to avoid additional costs and longer processes, like building contractors and conservationists in the design process.

- There are several ways to cooperate in order to guarantee that the limited financial resources will be used effectively, it seems promising to establish a peer review team which first aims to implement the easily achievable and quickly recoverable measures. A revolving fund seems to be an effective way to finance energy efficient measures.

- Other ideas focus on new partnerships, ike partnerships between owners of historical buildings who share the same interests of partnerships between owners and market parties. Also it seems promising to involve experts in an early phase of the project in order to avoid additional costs and longer processes. Examples are the involvements of building contractors and experts for the preservation of cultural heritage in the design process.

RECOMMENDATIONS FOR FURTHER RESEARCH

The recent Dutch programs focus on the improvement of the indoor climate in class rooms. There are no special programs for energy saving and improvement of the indoor climate for historical school buildings. The possibilities for interventions in historical schools are limited and often lead to higher costs than in modern school buildings. On the other hand historical schools are appreciated and we thus want to keep their function. From this point of view the suggestion of the revolving funds for energy saving measures in historical schools seems to be promising – either on local or on national level. If it is possible to establish a fund on a national level different energy saving measures in historical school could be realized in different cities and the savings could be re-invested in other schools in other cities.

However, in order to find out whether a national revolving fund is realistic the number of schools that is located in historical buildings must be known. The research of the TU Delft [1] shows that 111 schools are located in historical buildings which are listed as national monuments, but in addition there are many schools located in local monuments and also in historical buildings which are not listed as monuments at all. As the possibilities for interventions are limited in these buildings, too, they should have the chance to participate in a national funds. Maybe a start can be made by one or a few pilots with revolving funds for historical schools on local level. These pilots may deliver valuable experiences for the establishment of a national fund.

Furthermore, it would be interesting to realize pilot projects with the suggested new partnerships – the partnerships between owners who share interests as well as partnerships between owners and market parties.

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