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Intelligent glazed facades for fulfilment of future energy regulations

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SUMMARY

This project aims at testing technologies for control of heat transfer, irradiation, mass transport and energy storage in order to investigate the potential of a intelligent dynamic glazed facade. Furthermore a development of algorithms for control of the technologies included in the facade, for use in the design phase, is done. The methods used are initially based on thermal building calculations. This analysis shows that a dynamic adaptive facade is the only way in which future office buildings can fulfil the energy regulations. By designing the facade according to the usage and the microclimate, the energy usage of the building can be lowered significantly and fulfil energy regulations for 2020.

KEYWORDS

Dynamic facades, solar shading, dynamic U-values, energy storage, facade design

INTRODUCTION

There is an overall architectural trend towards more glazed facades. Transparency is becoming a more popular choice when designing the facade. The high transparency gives good opportunities for high daylight levels in buildings and minimizes energy consumption for electrical lighting. However there are drawbacks of these facades as more glazing gives a higher cooling and heating demand. As future energy regulations aim at reducing energy demand of new buildings, there is a need for improving the performance of the glazed facades, in order to keep glazed facades as a beneficial envelope choice.

Future energy regulations in Denmark aim at reducing the energy demand from buildings by 25% (71 kWh/m^2 pr yr) in 2010, 50% (48 kWh/m^2 pr yr) in 2015 and 75% (24 kWh/m^2 pr yr) in 2020 compared to the present energy regulations (95 kWh/m2 pr yr), [EBST]. Furthermore the energy demand should be reduced to near zero through the use of renewable energy sources on site or off site near the building [COM(2008) 780 final].

This paper focuses on two approaches in order to fulfil future energy regulations:

- A static approach focusing on optimizing components in the facade.
- A dynamic approach focusing on adaptive technologies in the facade.

There are many ways in which to fulfil future energy regulations. However some of the possibilities for lowering energy usage of buildings are focused on optimization of systems or components, increasing of heated space area, reduction of the glazed area, or even including large areas of renewable energy harvesting. These optimizations are often done in order to fulfil the energy regulations. However an adaptive facade approach can lead to lower energy consumption and fulfilment of user demands.

The intelligent glazed facade has the potential of fulfilling future energy regulations in 2020 without implementing renewable energy harvestings technologies on the building while still being able to adapt to the user demand. This paper shows this through the introduction of adaptive and dynamic facade solutions.

METHODS

The methods used in this article are based on thermal building simulations, using the program BSim [SBi-BSim] and Be06 [SBi-Be06], since these programs are the main programs used in Denmark.

The comparisons between the dynamic facade solutions and the static facade solution are made under the assumption that the glazing area remains constant and the facade layout is the same thereby keeping the architectural expression the same. The differences between the calculations are based on the technologies included in the facade.

Reference building

The potentials in this article are based on an energy calculation for an office building with a total heated space area of approx. 10.000m^2. This calculation is based on the assumption that the windows used have a total U-value of 1.5W/m^{2}K and a g-value of the glazing of 0.6. The ventilation unit has an average SFP-factor of 2.1kJ/m^3. As with other glazed buildings, the building is determined as a relatively light building with regards to the thermal mass.

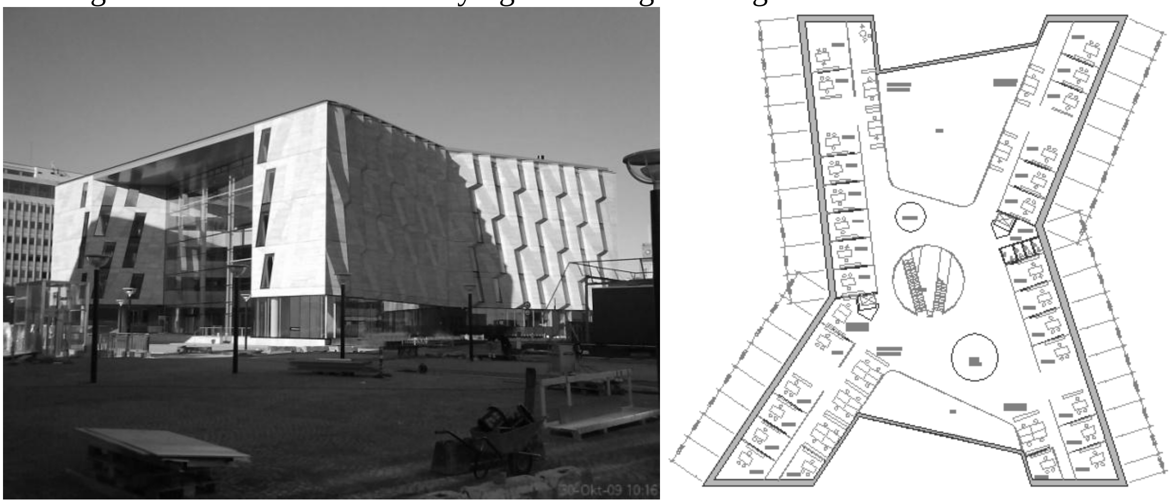

Figure 1: Illustration and plan drawing of the reference building.

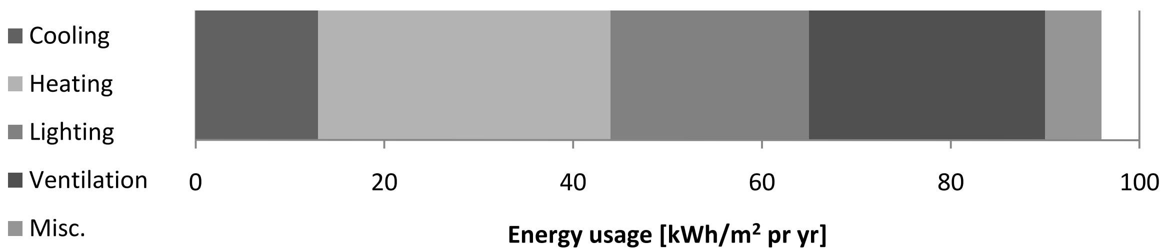

Figure 2: Distribution of energy usage from a typical office building.

This gives at total energy demand of 96kWh/m^2 pr yr thereby fulfilling the energy requirements for BR08. Most energy calculations for office buildings have the same energy demand for cooling, heating, lighting, and ventilation. The most influential parameter for these types of buildings is therefore the facade, since this is the only parameter which deviates substantially from the standard calculations of energy demand for office buildings, due to the constant values of the internal load and buildings usage time [SBi-213].

RESULTS

The static facade

By looking at the facade with a static approach to reduce the energy demand, the reduction of the heating demand can be done by choosing a better insulating window solution by improving the coating on the glazing, improving the gas in the cavity, better insulting frames, improved spacer, or even including more layers of glazing. The total U-value of the window can by such solutions be reduced to 0.7 W/m^{2}K. In this calculation it is assumed that the improvement does not influence other factors. However it will of course have influence on the light transmittance and the g-value if more layers of glazing are installed. This improvement reduces the energy demand for heating from 31 kWh/m^2 pr yr to 15 kWh/m^2 pr yr. However the cooling demand is increased from 13 kWh/m^2 pr yr to 17 kWh/m^2 pr yr. This is due to the fact that the building cannot release the heat in warmer periods, where a higher heat loss would have been beneficial. The total energy demand from the building is reduced from 96kWh/m^2 pr yr to 85kWh/m^2 pr yr, Figure 3.

In order to reduce the energy demand for cooling a change of glazing type is required. By keeping in mind that the changes done in this approach the choice of glazing is changed from clear glazing to a solar reflective glazing thereby reducing the g-value from 0.6 to 0.25. This change also influences the light transmittance due to the relationship between g-value and LT-value. The LT-value therefore reduces from 0.7 to 0.3 leading to a reduction in daylight level by a factor of 2.3 thus resulting in an increase in the energy demand for lighting. As a result of this, the energy demand for cooling is reduced from 17 kWh/m^2 pr yr to 4 kWh/m^2 pr yr. However the energy demand for heating increases from 16 kWh/m^2 pr yr to 20 kWh/m^2 pr yr due to the lower passive solar heat gain in the colder periods. Due to the decrease in daylight level by a factor of 2.3 the energy demand for lighting is increased from 21 kWh/m^2 pr yr to 37 kWh/m^2 pr yr. The entire energy demand increases from 85kWh/m^2 pr yr to 92kWh/m^2 pr yr, Figure 3.

By changing the light control-system of the building, from a manual control-system to a more intelligent solution, with a continuous light control, the energy demand for lighting decreases from 37 kWh/m^2 pr yr to 16 kWh/m^2 pr yr. The energy demand for heating increases due to a lower internal heat-load. Furthermore the energy demand for cooling decreases. The entire energy demand is reduced from 92kWh/m^2 pr yr to 73kWh/m^2 pr yr, Figure 3.

The total influence from applying these static solutions to the facade does not reduce the energy demand significantly in order to fulfil the energy regulations for the future. Even though the products used are state of the art and sub optimized, the entire energy demand remains within the regulations for BR08 and BR2010. The solutions imposed to the building, influences the entire energy demand both positively and negatively, Figure 3.

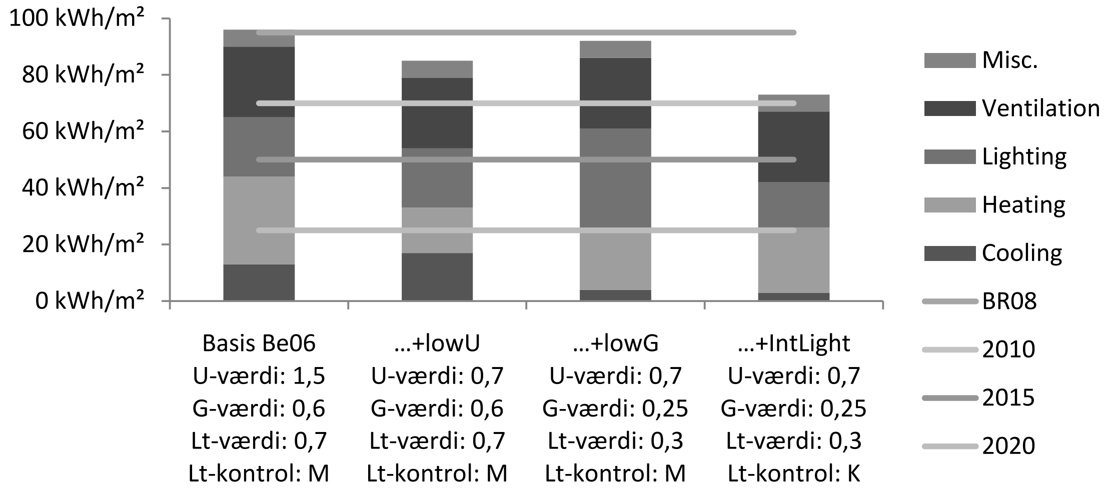

Figure 3: Total change in energy demand as a function of static solutions.

The dynamic facade

By applying dynamic solutions to the facade for control of heat transfer, irradiation, mass transport and energy storage, the building is able to adapt itself according to the environment and the demand from the user. Intelligence is introduced to the control strategy for the technologies applied enabling the building to optimize itself according to the demand and possibilities. The following sections are focused reducing the energy demand of the building presented in Figure 2.

Dynamic heat transfer control can be introduced through the use of shutters with insulating effect. This can be achieved through the use of many of the existing materials, since a small amount of insulation has great influence of the U-value. For instance if 1.5 cm of aerogel, with a heat conductivity of 0.015 W/mK, is applied to the window with a U-value of 1.5 W/m^2K, the entire U-value of the window can be changed from 1.5 W/m^2K to 0.5 W/m^2K. As a result the energy demand for heating is reduced from 31 kWh/m^2 pr yr to 14 kWh/m^2 pr yr and the cooling demand is reduced from 13 kWh/m^2 pr yr to 10 kWh/m^2 pr yr due to the possibility for the building to control the heat loss through the facade both in warmer periods and cooler periods. The entire energy demand is reduced from 96kWh/m2 pr yr to 76kWh/m2 pr yr thus almost fulfilling the energy requirements for BR2010 simply by applying dynamic heat transfer to the transparent part.

In order to reduce the energy demand for cooling, dynamic g-values are applied to the glazing. This technology can be introduced to the facade through the use of state of the art materials for glazing with sunlight responsive thermochromic technology enabling the g-value to fall as a function of irradiance on the facade. However simpler ways of obtaining the same effect can be achieved through the use of external solar shading. With present technologies, it is possible to reflect around 90% of radiation thus enabling the g-value to change from 0.6 to 0.1. This technology reduces the energy demand for cooling from 10 kWh/m^2 pr yr to 1 kWh/m^2 pr yr. The energy demand for heating increases from 14 kWh/m^2 pr yr to 17 kWh/m^2 pr yr due to control of the maximum irradiation and therefore the thermal heat storage capacity. The entire energy demand for lighting remains unchanged, due to the control strategy of lighting, where the solar shading is turned on after the lighting levels are achieved. Special attention should be made to the heat gain from general lighting since this can result in an increase in cooling demand if the solar shading is turned on before obtaining sufficient lighting levels within the office space. As a result of this technology, the entire energy demand is reduced from 76kWh/m^2 pr yr to 70kWh/m^2 pr yr.

The energy demand for ventilation can also be reduced by utilising decentralized ventilation combined with natural ventilation. The benefits of using decentralized ventilation in combination with natural ventilation, is the significant reduction in SFP factor due to the small pressure loss in the ducting works. The yearly averaged SFP factor can easily be reduced from 2.1kJ/m^3 to 0.4kJ/m^3 with the combination of natural and mechanical ventilation. The change in SFP factor, results in a reduction of the energy demand for ventilation from 25 kWh/m^2 pr yr to 6 kWh/m^2 pr yr thus giving a change in the entire energy demand from 70kWh/m^2 pr yr to 51kWh/m^2 pr yr and thereby almost fulfilling the energy regulations for BR2015.

As with the static solution, intelligent continuous light control can be introduced to the buildings light control system. This results in a reduction of the energy demand for lighting from 21 kWh/m^2 pr yr to 8 kWh/m^2 pr yr. The entire energy demand is reduced from 51 kWh/m^2 pr yr to 40 kWh/m^2 pr yr.

In order to increase the thermal mass of the building, phase change material (PCM) can be included in the technologies applied on the facade, e.g. the solar shading or the glazing. However BSim cannot calculate this combination of technologies. The thermal mass is therefore increased on the interior construction parts. Since the technology of PCM has a different cp-value as a function of temperature, BSim cannot calculate this technology when included in the glazing or the systems connected with the windows. However the results with an increase in the thermal mass indicate a reduction in the energy demand for heating from 20 kWh/m^2 pr yr to 17 kWh/m^2 pr yr and an entire energy demand of 37kWh/m2 pr yr. The effect of using PCM is however not shown in these results since the thermal heat capacity would be greater at around 23°C.

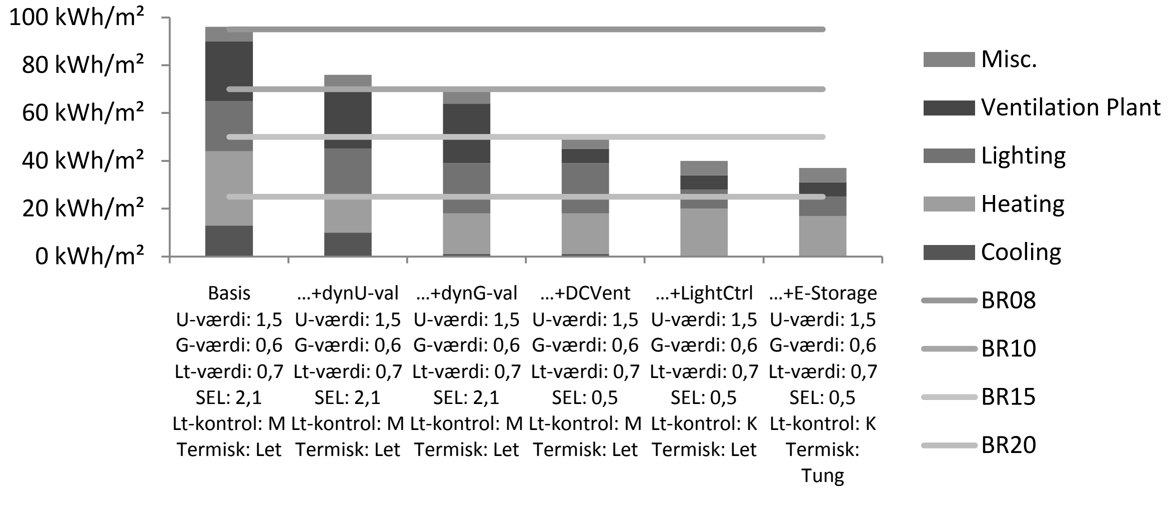

Figure 4: Total change in energy demand as a function of dynamic solutions.

Another interesting aspect of these optimizations are that the building changes character from being a building requiring both heating and cooling, the building now only requires heating. Looking at the infiltration, and trying to optimize this parameter, the energy demand for heating can also almost be eliminated if the infiltration is reduced from 0.3 /hr to 0.15 /hr. The entire energy demand for the building is reduced to 23kWh/m^2 pr yr thus fulfilling the energy regulations for 2020 without implementing renewable energy harvesting, Figure 5.

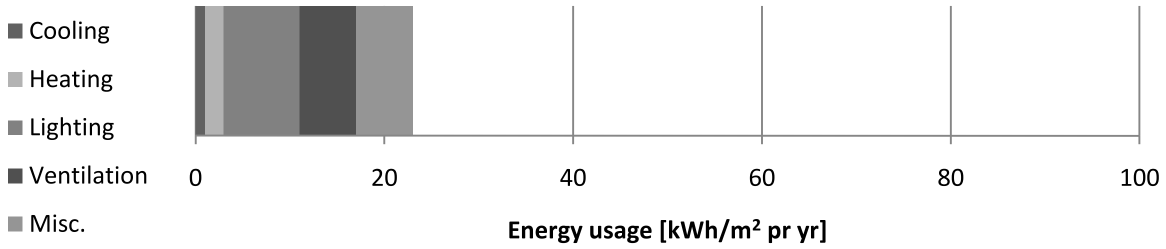

Figure 5: Distribution of energy usage from a typical office building with dynamic façade technologies included. The total energy demand is 23kWh/m^2 pr yr.

DISCUSSION

The results from this study shows that there is a potential in thinking the façade as part of the system solution to minimizing energy demand instead of focusing on optimizing single components. It is extremely important to understand that a correctly designed and controlled façade almost can result in elimination of heating and cooling systems. Even though some of the technologies applied to the façade are more expensive, the opportunity of substituting an entire system has great potential.

Furthermore façade design as an engineering discipline in collaboration with architects can result in spectacular dynamic architecture. Understanding the energy transport in the façade is vital to the systems presented here. Since the basic technologies used fulfills the energy regulations for BR08, but by introducing new dynamic solutions the building can fulfill energy regulations for BR2020, a potential flaw of a technology or construction can result in a much higher energy demand, as also known throughout the cases where advance integrated façade solutions have been used in practice.

CONCLUSIONS

This article shows that introduction of dynamic façade solutions to regular office buildings, can reduce the entire energy demand significantly and fulfill energy regulations for BR2020. Furthermore the results from the static solutions shows that the energy demand cannot be reduced significantly simply by optimizing technologies.

U-values are for example heavily correlated with cooling demand, and g-values are heavily correlated with heating demand. A focus only on one of these energy demands will result in higher energy demand of the other and not necessarily a reduction of the entire energy demand.

Focus should be put on design and control of the façade in correlation with the usage of the building and the microclimate as well as the architecture.

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REFERENCES

COM(2008) 780 final, DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings, Brussels, 13.11.2008, COM(2008) 780 final, 2008/0223 (COD), COMMISSION OF THE EUROPEAN COMMUNITIES

EBST, http://www.ebst.dk/publikationer/Strategi_for_reduktion_af_energiforbruget_i_bygninger/html/chapter07.htm

SBi-213, SBi-anvisning 213 Bygningers energibehov, Beregningsvejledning, version 4.08.07, 2008, Søren Aggerholm, Karl Grau

SBi-Bsim, http://www.sbi.dk/indeklima/simulering

SBi-Be06, http://www.sbi.dk/miljo-og-energi/energiberegning