Benefits of various types of shading and night cooling by vent windows

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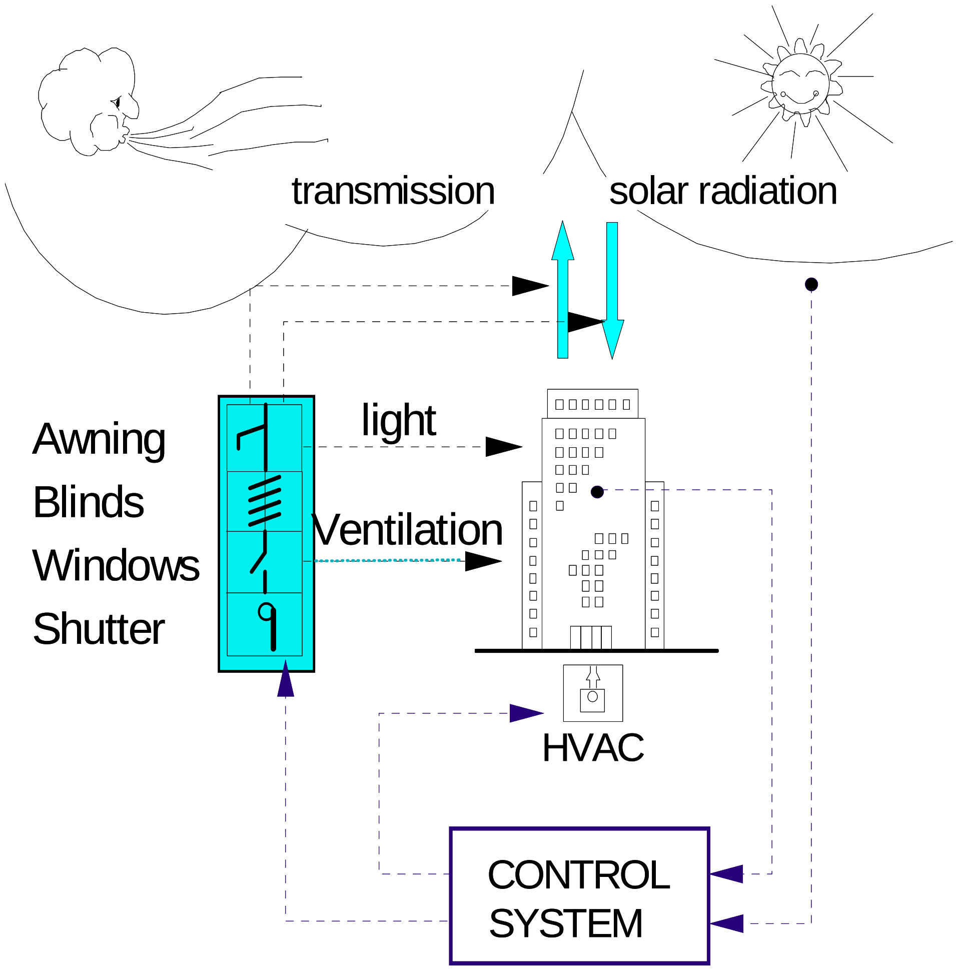


Intelligent facades: integrated control of the building façade and Heating Ventilating and Air Conditioning.

Benefits of various types of shading and night cooling

Content

1 Introduction

The solar shading industry became aware of the impact of their products on the reduction of energy, CO_2 emission, comfort and productivity. The umbrella trade organization ESSO (European Solar Shading Organization) claims substantial energy savings from solar shading. In a well founded paper (ES-SO, 2006) this was demonstrated.
This notion is intensified by the European Commission that issues the Directive on the Energy Performance of Buildings (EPBD). This Directive stimulate Member States to find ways to reduce the energy consumption of buildings by more than 20%. Taken into account that buildings (office buildings and dwellings) are using 40% of Europe's total primary energy, this objective can only be obtained when every potential source of energy saving will be applied and- as will be demonstrated in this report- good solar shading systems are the first.

SOMFY, a manufacturer of control equipment for solar shading and other window systems worldwide, goes one step further by introducing the INTELLIGENT FAÇADE concept that combines the control of solar shading, vent window and Heating Ventilating and Air Conditioning system (HVAC).
In this publication a scientific feasibility study will be made about these types of facades, their impact on the performance of HVAC and energy consumption.

INTELLIGENT FACADES combined with the Heating Ventilating and Air Conditioning systems (HVAC) are ready to be applied in practice. As indicated in figure 1 it can have controllable inside and/or outside blinds, window openings, shutters, double skin with dampers and blinds inside etc..
Control of these systems are based on the philosophy: " use first natural sources such as sunshine for day lighting and passive heating and wind for ventilation and cooling. As soon as it is no longer sufficient then switch over to artificial lighting or HVAC". This approach leads to low energy consumption and low capacities of the installations with following low costs.

Most studies in literature are based on the energy savings that can be obtained by more advanced shading systems, while in this study it will be shown that the impact on the design of HVAC is much larger. In most cases these shading systems not only lead to lower energy consumption but particularly to smaller HVAC installations and consequently to lower costs.

The same accounts for motorized vent windows. Various international research project funded by EU such as NatVent® show that natural ventilation for fresh air supply and cooling is a sustainable solution. Especially night cooling by excessive ventilation through the opened windows are very effective. For comparison: typical ventilation rates of mechanical ventilation systems are 2 à 3 while by open windows ventilation rates between 5 à 10 happen without using any energy at all. This makes, that rooms with low internal loads (< 25 W/m^2 floor area) do not need mechanical cooling. In general, energy savings and reduction in cooling capacities are high if cooling by natural ventilation is applied first and mechanical cooling is switched on only when natural means are no longer sufficient.

In these report the impact of controlled components of the façade such as blinds and vent windows are investigated with respect to CO_2 emission, energy saving and costs.
Although good interfaces between inhabitants and window systems are needed to adjust window systems according their wishes, these items are not discussed here.

2 Objectives

Designing intelligent façades need answers on following questions:

- Is any shading needed?
- If the answer is yes, which one should be selected?
- How should the selected shading system be controlled?
- What are the benefits with respect to energy saving, CO_2 emission and costs?
- Should the shading system be combined with the control of vent windows in order to cool the building at night (night cooling) and how much cooling capacity and energy consumption of the HVAC installation can be reduced then?

It is the objective of this report to generate typical values of energy and capital costs and CO_2 emission in order to make optimal choices.

3 Solar shading systems and controlled vent windows

The various shading systems are:

- No shading at all (double normal glass)
- Indoor Venetian blinds
- Outdoor Venetian blinds

Following mode of control for the various shading systems can be applied:

- Fixed position during the whole year. The shading is down during the whole year

- Position controlled by sunshine.
  If the sun radiation on the outside surface of the facade is less than some threshold value , then the shading will be up, else it will be down.

- Continuously controlled

  The position of the shading is continuously changed to fulfil the desired minimal illumination level in the living space of for example 500 Lux. During the night the shading will be up.

3.1 Systems to be analyzed (energy and capital costs)

Not all combinations of the shading systems, night cooling and control have to be considered. Beforehand it can be reduced to 6 alternatives. This makes the presentation more conveniently arranged. These alternatives are:

0) Normal double glass with indoor Venetian blinds always down. There is artificial lighting control. It is switch on when the lighting level on the desk is lower then 500 Lux. The artificial light controller will fill up the gap by increase power when natural day lighting is further decreasing.

This type of artificial lighting control is supposed to be standard and in operation in all the other alternatives considered.

1) Double glass without any solar protection. This option is considered although it will not be acceptable from a lighting point of view.

2) Outside Venetian blinds are applied without control. It is put always in the lower position with vanes at 45 °.

3) Outside blinds as 2) with control. It is let down when solar radiation on the outside surface of the window is higher than 250 W/m^2.

4) Outside blinds are used for controlling the light level inside the room. When the average illumination on a writing desk is above or below the setpoint of 500 Lux then the position of the blinds are put in such a position that the desired lighting level will be obtained. As soon as the blinds are in the most transparent position then the artificial lighting control takes over.

5) The same situation as 4) with motorized ventilation window for night cooling. The control of the vent window is carried out by controlling the indoor temperature outside office hours at a low setpoint (21°C) as long as the outside temperature is above 15°C.

With the computer program Enerk these alternatives are analyzed with respect to energy consumption, costs and CO_2. See chapter 5. They are indicated by the numbers 0 to 5 and the pictures shown in figure 1.

All cases have the same type of HVAC system (induction system). This system supplies fresh air at 16°C from a central air handling installation and controls locally the indoor temperature by a unit with heating and cooling facilities.

Window systems indicated by 2) to 5) are indicated further on as “advanced”.

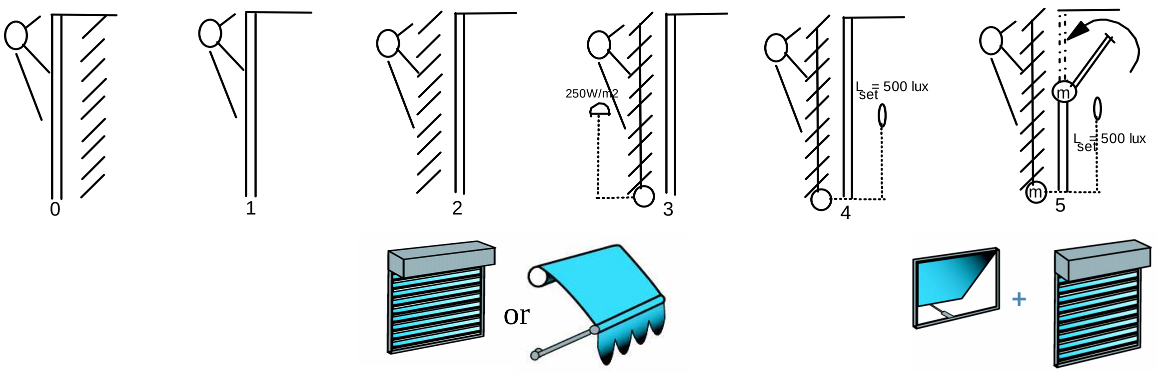
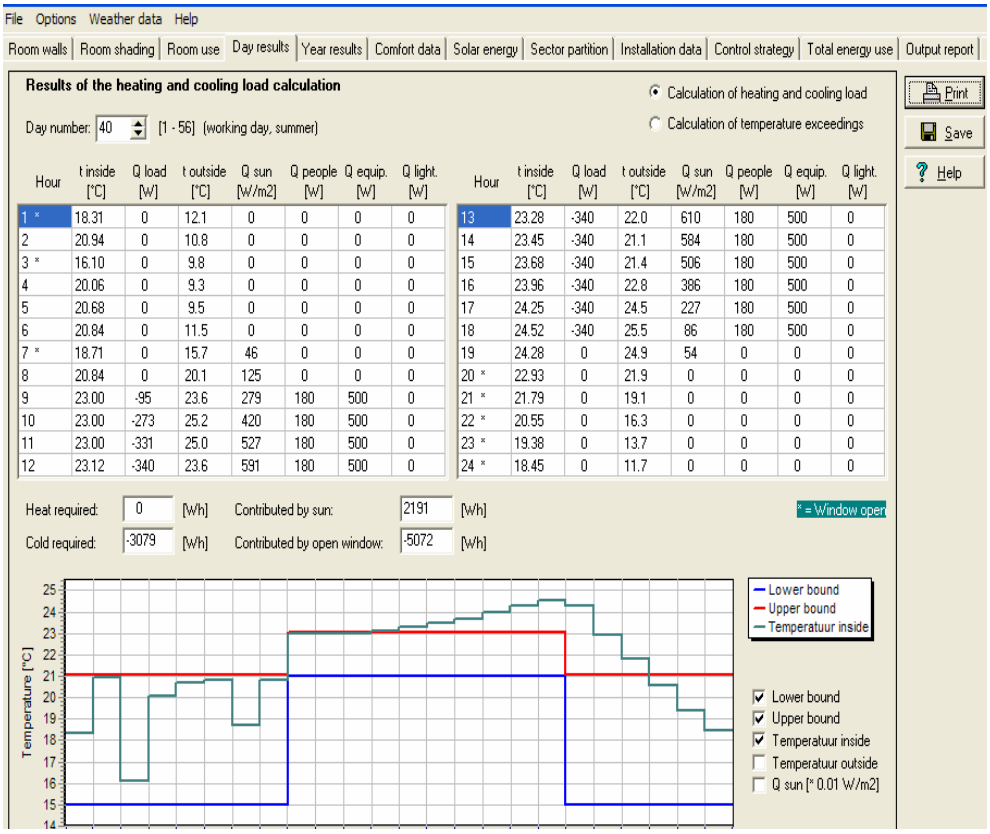


Figure 1. Alternatives considered for analyses.

3.2 Night cooling

Frequently night cooling is not applied in the most effective way. Therefore, more attention is given here.

The benefits of night cooling is very sensitive for the control strategy. During summer nights the building should be cooled down 1 or 2 K below the lowest comfort level that can be accepted during office time, being 21°C. If this is not done, and it is controlled at the same comfort level as applied during the office time (23°C) then the benefits of night cooling will be disappointing. To get effective night cooling it should be cooled down deliberately to lower temperatures. This can be done in Enerk (see chapter 4) by putting the upper temperature level during night at 21 °C. The result is that the energy consumption for heating is increased slightly because of some mismatches, but on the other hand the cooling capacity and energy consumption for cooling are decreased dramatically.



Hour	t inside [°C]	Q load [W]	t outside [°C]	Q sun [W/m2]	Q people [W]	Q equip. [W]	Q light. [W]
1 *	18.31	0	12.1	0	0	0	0
2	20.94	0	10.8	0	0	0	0
3 *	16.10	0	9.8	0	0	0	0
4	20.06	0	9.3	0	0	0	0
5	20.68	0	9.5	0	0	0	0
6	20.84	0	11.5	0	0	0	0
7 *	18.71	0	15.7	46	0	0	0
8	20.84	0	20.1	125	0	0	0
9	23.00	-95	23.6	279	180	500	0
10	23.00	-273	25.2	420	180	500	0
11	23.00	-331	25.0	527	180	500	0
12	23.12	-340	23.6	591	180	500	0
13	23.28	-340	22.0	610	180	500	0
14	23.45	-340	21.1	584	180	500	0
15	23.68	-340	21.4	506	180	500	0
16	23.96	-340	22.8	386	180	500	0
17	24.25	-340	24.5	227	180	500	0
18	24.52	-340	25.5	86	180	500	0
19	24.28	0	24.9	54	0	0	0
20 *	22.93	0	21.9	0	0	0	0
21 *	21.79	0	19.1	0	0	0	0
22 *	20.55	0	16.3	0	0	0	0
23 *	19.38	0	13.7	0	0	0	0
24 *	18.45	0	11.7	0	0	0	0

*Figure 2. Indoor temperature response when night cooling is applied. Opened windows are indicated by *. The highly fluctuating indoor temperature during night is caused by open/closed control of window opening and the time step of 1 hour. In reality it will be more smooth.*

3.3 Adaptive comfort temperature

More and more it becomes clear that people's sensation of thermal comfort changes during the year. This is especially so for the maximum temperature. Higher temperatures are accepted in summer then in spring.
Therefore a new criterion is proposed in the Netherlands called “Adapted weighted

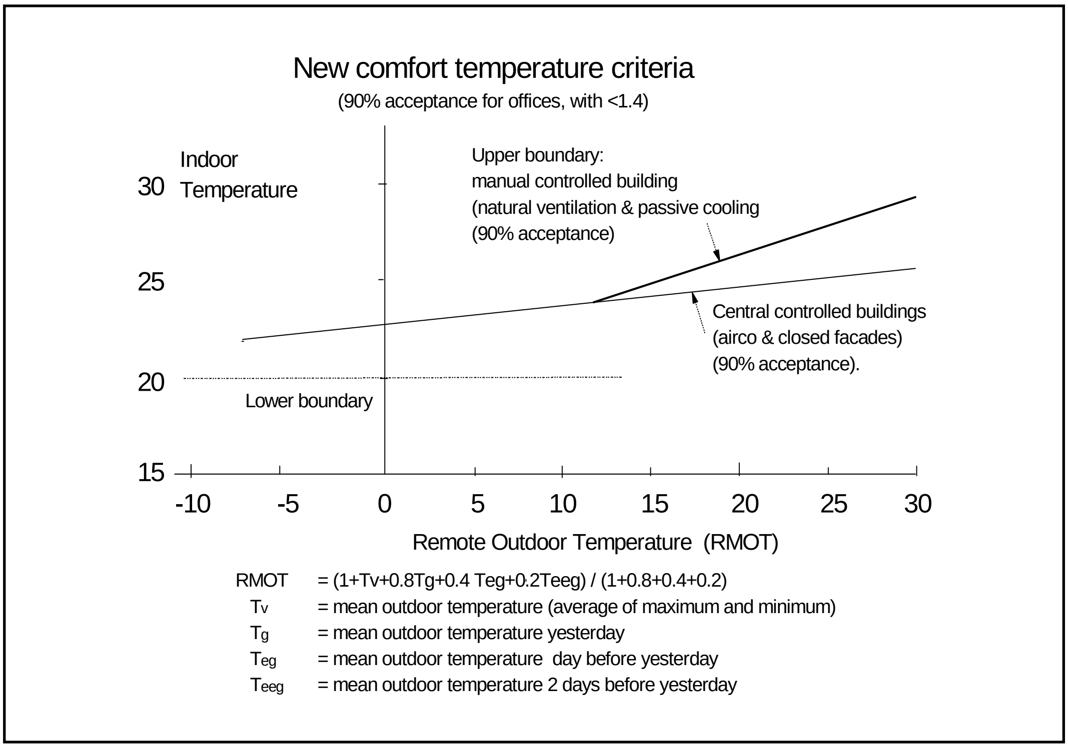


Figure 1.1
Adaptive comfort criterion as proposed in The Netherlands.

temperature exceeding". In figure 1.1 it is shown how the acceptance of indoor temperatures are changing with the moving average of the outdoor temperature (remote outdoor temperature, RMOT). All temperatures between the upper and lower limit are accepted by 90% of the people. The lower limit is 20 °C while the upper limit is increasing with the outdoor temperature. It shows that people in buildings with passive cooling by open windows accept much higher temperatures. At a remote outdoor temperature of 28 °C an indoor temperature of 28°C is accepted, while in buildings with air conditioning and closed facades the limit is 25°C. Therefore two upper limit curves are given. A similar criterion will be accepted in the European standard prEN 15251, called Criteria for the Indoor Environment including thermal, indoor air quality, light and noise.

It can be seen that the new criterion is less severe for natural ventilated buildings with operable facades and individual control. The indoor temperature at extreme warm weather conditions may be 3 K higher. This means that for buildings with intelligent control of the façade chillers can be omitted in most cases, reducing the energy and costs enormously.

Although the adaptive criterion is very advantageous for applying intelligent facades, it is not considered in this report, because so far it is not yet accepted as a general rule. But sooner or later this kind of psychological aspects will play an important role!

4 Tools for analyses (Enerk).

The calculations are carried out for a medium weight building, facing south and for internal loads (heat generated by people, machines and lighting) of 20 and 40 W/m^2. Detailed information is given in the Appendix (10.1) as screen dumps of the input parameters for Enerk.
Enerk is a computer program to design HVAC systems in close connection with the façade and its solar shading devices. It can be used at the early stage of a project to make well grounded selections cut of the maze of possibilities. By its interactive approach and help files it will guide the designer to the best solutions with respect to energy consumption, CO_2 and costs. See Appendix (10.2) to form a picture of the use of the program.

4.1 Validation of the cost model

In Enerk the costs are estimated based on the capacities of the installations and the costs of components generally accepted by the Dutch market (Olst, 2004). These capacities deliver the purchase prize of the installation. The yearly capital costs are found by multiplying the purchase value with a constant factor (here 8% was chosen).

It should be clear that the costs model is not meant for predicting the absolute values of the capital costs very precise. However, to get confidence the model is compared with the costs calculated for a specific building. Consultants, that make the calculation for that specific building, found for the HVAC installations a purchase prize of € 156,-/m^2 brut floor area. Consequently, for a standard room of 20 m^2 the yearly capital costs per room will be € 374 (taken into account that the brut floor area is 1.5 times the net surface and 8% interest is paid). In Enerk for a similar room the value of € 350 is found. From this fact it may be expected that the costs model gives realistic values.
Of course the cost per component and the interest can be changed in Enerk by the user. However, the choice of reasonable values will not change the overall trend of the output.

4.2 Validation of the thermal aspects

Enerk is compared with the output of a simulation program made for analysing double skin facades with some of the advanced window systems as mentioned in this report (Stec, 2006).

In Appendix 8.4 the results are shown graphically by figure A1 and A2. It can be concluded that the energy consumption shows in general a good match, but the cooling capacity is calculated higher by Stec. However, the sensitivity for the window system is the same for both programs. This means they predict both the same reduction in installation capacities and that is what counts here.

5 Calculation results. Impact of shading and night cooling

The calculation results are combined in figure 3. The calculations are done for low and high internal loads, 20 and 40W per m^2 net floor area respectively generated by people, light and machines. The main conclusions of this report will be based on 40W per m^2, because this load occurs frequently in office buildings.
It might be interesting to remind the climate used for the simulation is the Dutch climate. However, from earlier calculations with data of a comparable climate region didn't change the overall picture.

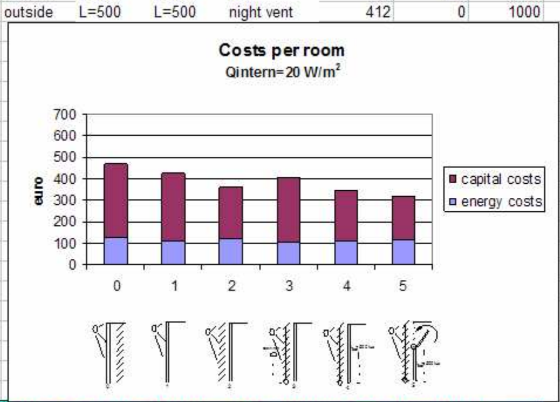
5.1 Analyses calculation results

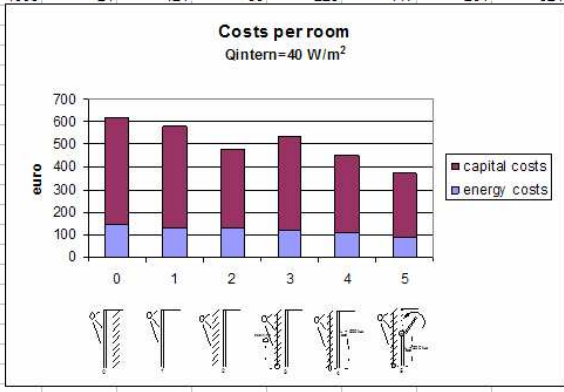
In general it can be concluded from the data that well controlled shading systems have large impact on cooling capacities of HVAC systems. The same accounts for energy costs although it is less. Capacities and capital costs are strongly correlated, thus the impact of shading systems on capital costs is high too. Especially, this is the case when the internal load is low and night cooling by vent windows is applied. In that case it can be decided to omit mechanical cooling with the consequence of a high costs reduction.
At high internal loads all controlled window systems lead to relatively lower energy costs. The same can be found by comparing the CO_2 emission.

Artificial lighting controlled at L=500 lux — Walls: floor/ceiling of 0.2m concrete; separation walls 0f 0.02 Gympsum board
Short reference year (de Bilt;NL) — Orientation: south; glas area= 3.8 m2 (40% of façade)
Medium heavy building — Dimension room: 5.8 X 3.5 X 2.7 m

Internal load 20W/(m2 floor): people:180; equipment:100; lighting 120 W.

					room level				Installation level					Yearly costs (euro)			CO2
code	solar protection blinds	control protection	control lighting lux	control window opening	Energy heating kWh	cooling kWh	Capacities heating W	cooling W	heating E+ kWh th	cooling E- kWh e	fan Efan kWh e	artificial lig Elighting kWh e	electricity total kWh e	energy	capital	total	kg
0	inside	no; down	L=500	no	200	670	1000	900	1484	143	119	199	461	125	347	472	471,98
1	no	no	L=500	no	175	761	1000	880	1462	172	117	69	358	111	315	426	428,44
2	outside	ever down	L=500	no	286	211	1000	300	1670	27	123	225	375	122	236	358	476,5
3	outside	Qsun>250	L=500	no	264	379	1000	540	1591	64	123	69	255	103	304	407	415,1
4	outside	L=500	L=500	no	393	119	1000	230	1878	23	124	80	226	112	232	344	461,48
5	outside	L=500	L=500	night vent	412	0	1000	0	1993	21	124	80	225	117	204	321	484,1





Internal load 40W/(m2 floor): people:180; equipment:500; lighting 120 W.

					room level				Installation level					Yearly costs (euro)			CO2
code	solar protection blinds	control protection	control lighting lux	control window opening	Energy heating kWh	cooling kWh	Capacities heating W	cooling W	E+ kWh th	E- kWh e	Efan kWh e	Elighting kWh e	electricity total kWh e	energy	capital	total	kg
0	inside	no	L=500	no	27	1696	1000	1400	1125	410	115	199	742	144	477	621	506,96
1	no	no	L=500	no	13	1742	1000	1360	1107	424	115	69	607	127	454	581	452,06
2	outside	ever down	L=500	no	39	1103	1000	780	1239	231	117	225	574	129	350	479	465,92
3	outside	Qsun>250	L=500	no	48	1310	1000	1000	1265	294	118	69	481	118	417	535	435,78
4	outside	L=500	L=500	no	60	905	1000	710	1347	182	120	80	382	109	345	454	414,56
5	outside	L=500	L=500	night vent	74	301	1000	340	1372	35	120	80	234	91	281	372	363,32

Figure 3. Calculation results with Enerk. All data are given for a standard room facing south with 40% glass area and 20 m^2 floor area.

Daylight control by changing the position of the blinds (system 4) gives at low internal loads (20W/m^2) higher energy costs than those proposed earlier. The reason is that by this type of daylight control less solar radiation will enter the room and consequently more heating should be supplied to compensate this. At higher internal loads (40W/m^2) the need for cooling is higher, so that less solar energy is advantageous.

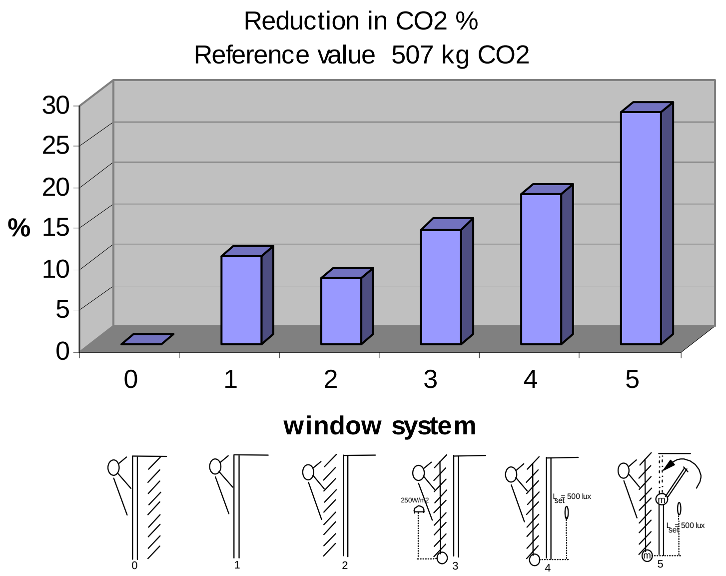


Figure 4. Emission of CO_2 per room (internal load 40 W/m^2 floor area)

The emission of CO_2 can be reduced with 18% by applying advanced solar protection systems when compared to the window system with uncontrolled indoor Venetian blinds (figure 4). It can be further increased to 28% when night cooling with motorized windows is applied. Consequently, advanced window systems can contribute substantially to solve the environmental problems.
The total energy for office buildings is more or less 10% of the national energy use. The reduction of CO_2 emission of 28% in office buildings can thus roughly be estimated at 3% for the whole country.

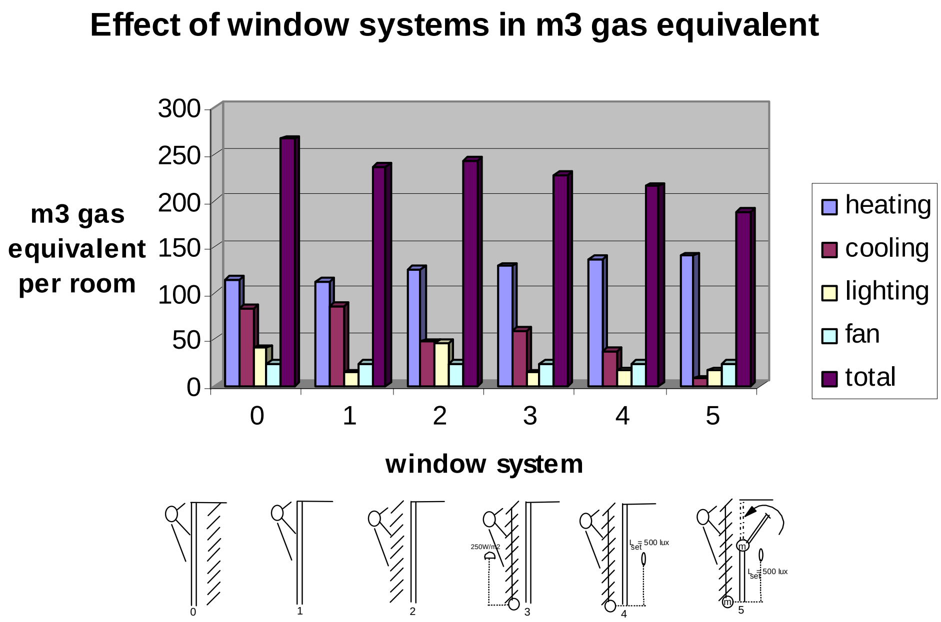


Figure 5. Primary energy per room needed for heating, cooling, lighting and transport.

In figure 5 the contribution of various window systems to the reduction of energy is clearly demonstrated. It is interesting to see that energy for cooling can be reduced almost to zero while heating is increased, but in total due to better lighting control and night cooling by natural ventilation the demand of fossil energy is reduced by 29%.

It is clear that an automated window system can contribute to energy saving, but are they cost effective?

In figure 6 it is clearly demonstrated without any doubt that advanced window systems are cost effective, but this is mainly caused by the reduction of the capacities of the climate installation that reduce capital costs dramatically. It shows that the extra costs for the window systems are overcompensated by the reduced costs of the installation. Energy is also decreasing but on a modest scale.

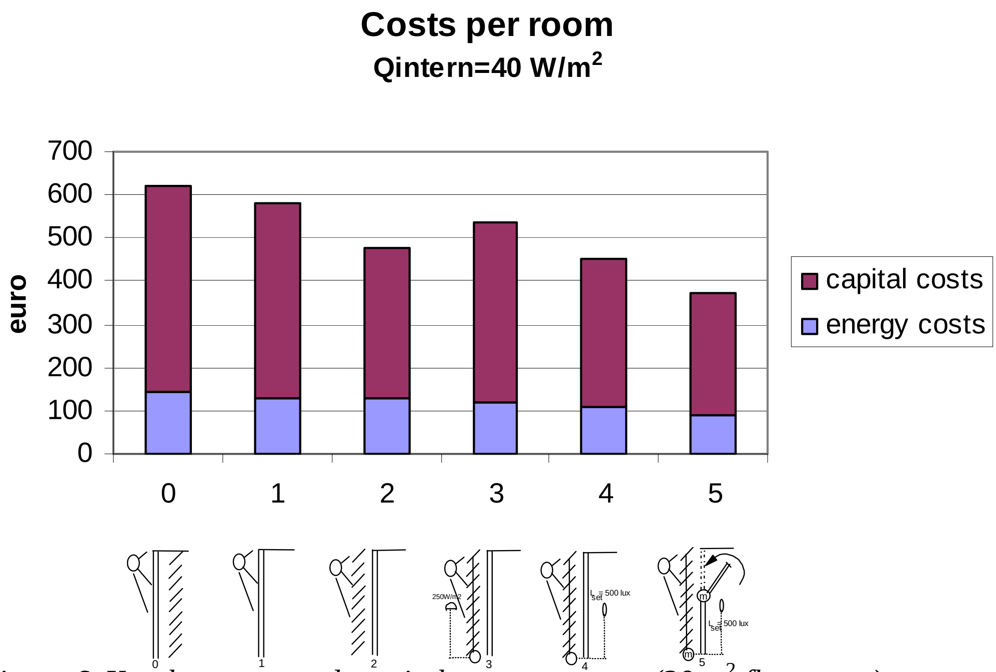


Figure 6. Yearly energy and capital costs per room (20 m² floor area)

5.2 Pay back times

Interesting results are obtained when the pay back time is defined for two different cases:

1) Integrated design of the façade and the climate installation. The façade expert will be involved at an early stage of the design and convince the architect and building owner to apply at least a more advanced window system.

2) The solar protection system is added to the building as an unavoidable item at the end of the design or even after the building is occupied by people that find out that it is impossible to read their screens. The HVAC installation is then designed conventionally for a closed façade with indoor Venetian blinds.

Table 1. Pay back times of the various window systems.
Data refer to a standard room with 20 m² floor area and 40 % window, facing south. Weather data of the Bilt in the Netherlands.
(In case façade and installations are integrated in an early stage of the design all advanced window systems pay back immediately. This result is upset when the window specialist is involved at the end of the design process. Then capacities can not be reduced by applying advanced window systems and consequently too long pay back periods will be found. With the result that advanced solar protection and day light control systems can not be promoted then. The situation becomes more promising when energy prices increase with 10% /year.)

1) Integrated design. **Capacities of HVAC are reduced in accordance with the window system.** Façade specialist is involved in an early stage of the design process. (Internal heat 40 W/m²)								
Window system No	**Type**	**Purchase costs HVAC (€)**	**Costs shading and vent window (€)**	**Costs HVAC + shading + vent (€)**	**Extra costs ref. to type 0 (€)**	**Energy costs / year (€)**	**Energy saving ref. to 0 (€)**	**Pay back in years**
0	Inside blinds. No control	5625	337	5962	0	144	0	**0**
1	No blinds	5675	0	5675	-287	127	17	**0**
2	Outside blinds, down	3625	750	4375	-1587	129	15	**0**
3	Outside blinds down Q_{sun}>250 W/m²	4312	900	5212	-750	118	26	**0**
4	Outside blinds controlled at 500 Lux	3412	900	4312	-1650	109	35	**0**
5	As 4 +night cooling	2312	1200	3512	-2450	91	53	**0**
2) No integrated design. **Capacities of HVAC are not reduced and designed for system 0.** Façade specialist is involved too late in the design process. (Internal heat 40 W/m².)								
0	Inside blinds. No control	5625	337	5962	0	144	0	**0**
1	No blinds	5625	0	5625	-337	127	17	**-**
2	Outside blinds, down	5625	750	6375	413	129	15	**27 (7)**
3	Outside blinds down Q_{sun}>250 W/m²	5625	900	6525	563	118	26	**22 (6)**
4	Outside blinds controlled at 500 Lux	5625	900	6525	563	109	35	**16 (5)**
5	As 4 +night cooling	5625	1200	6825	863	91	53	**16 (5)**
Future scenario: **(..)** = pay back in years at 10% increase per year of energy prices								

In table 1 these two cases are analysed. The upper part gives the costs of HVAC and the additional costs of the window system that should be made to control day lighting, solar protection and cooling by natural ventilation. Here the reduced cooling capacity and its effect on the cost are taken into account. In the lower part of the table it is assumed that the design of HVAC was based on the traditional approach: inside Venetian blinds without any control. The cooling capacities are much higher now. It delivers high pay back times in the order of 16 years.

The integrated design reduces costs dramatically. The reason is that the reduction in cooling capacity by applying more advanced window systems decreases total costs for the installation enormously. Therefore, this reduction together with the modest energy saving results in a positive balance for the integrated approach.

It can be concluded that the extra costs for the advanced solar protection, even combined with vent window systems, delivers profit right away. This can not be said of the last minute solutions with conventional cooling capacities.

Then the window specialist is involved at the end of the design process and capacities are already fixed and can not be reduced by applying advanced window systems. The consequence is that too long pay back periods will be found, as can be seen in figure 7. The situation becomes more promising when energy prices increase with 10% /year. Reasonable pay back times are calculated then.

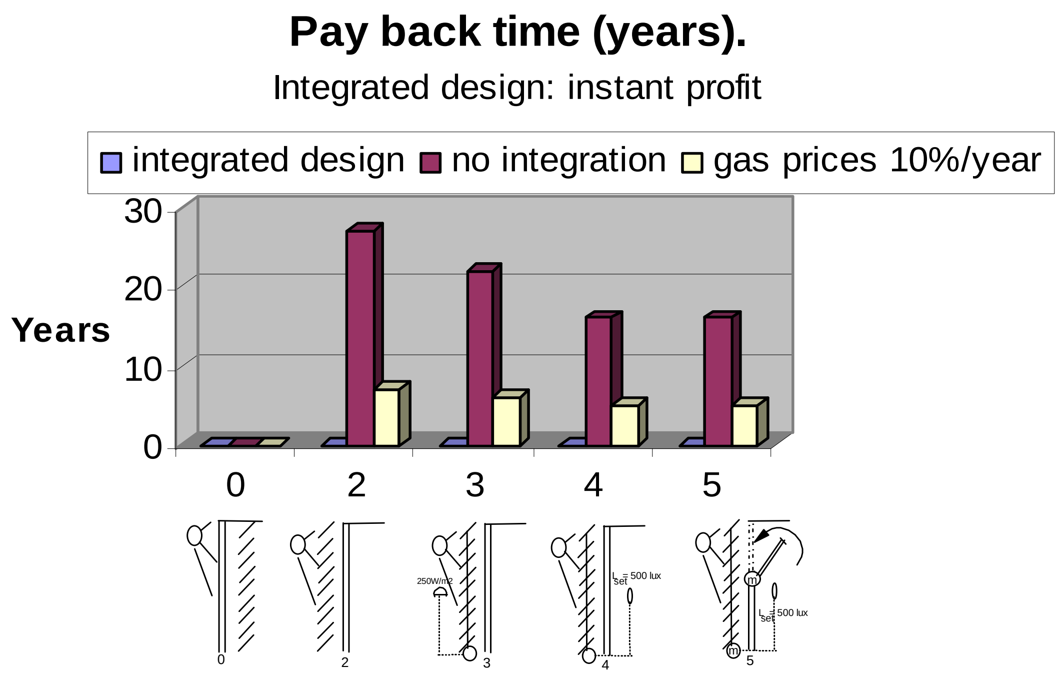


Figure 7. Pay back time. Integrated design reduces the capital costs of the installations in such a way that the extra costs of the advanced window system is fully compensated. This count for each window system. For the non integrated design long pay back times are found.

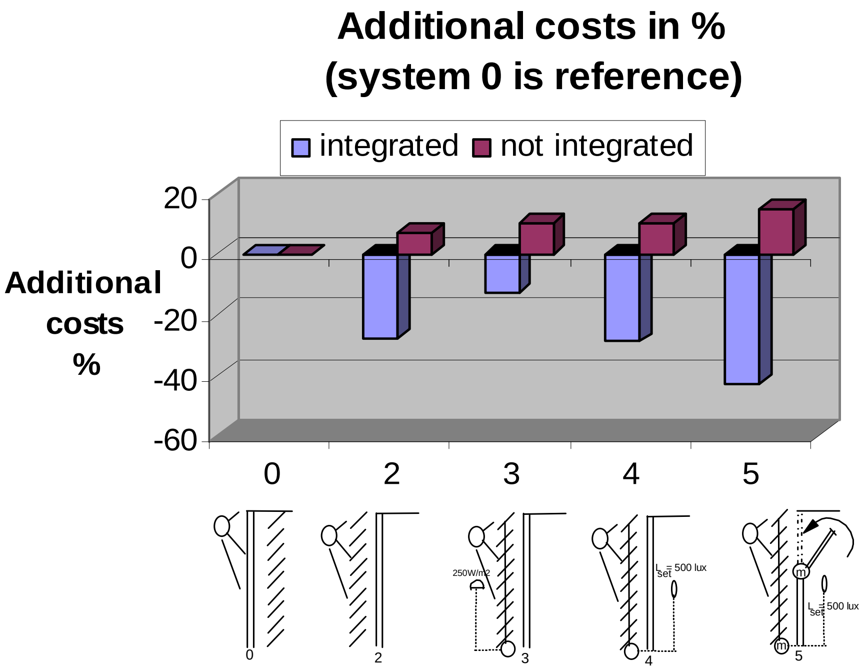


Figure 8. Total additional costs per window system compared to window system 0 for integrated and non integrated design. (Integrated design gives negative values. This should be read as gains)

In figure 8 the additional costs that should be made above that of the simple system (number 0) are shown in percentage. For the integrated design these values are negative, because of the dominant effect of capacity reduction of the HVAC installation. For example, the costs reduction due to the advanced solar protection system no 4 is 29% , while adding night cooling by controlled vent windows makes the reduction even 43%.

5.3 Marketing

From the results mentioned above it can be concluded that manufacturers of window systems should have an impact in the early stage of the design in order to promote their advanced products. They can easily show that their products can be very cost effective because of the fact that they can reduce the capacity and therefore the costs of HVAC systems substantially. It is of great importance that this information should pass on architects, real estate developers and building owners.

If the manufacturers plays no role in the early stage of the design then it will be faced with oversized installation designs. The energy saving, that is the only factor then, will not convince the client when pay back times of 16 years are mentioned. It is absolutely necessary to focus the client right from the beginning of the design process on the reduction of HVAC installation capacities. Then right away very attractive savings will convince the client. However, when energy prices are supposed to increased with 10% per year the pay back time for the non integrated design will be reduced to 5 years. Thus even then this situation becomes attractive.

6 Conclusions

- In general it can be concluded that the more sophisticate shading system has a much larger impact on capacities of heating, ventilating and air conditioning installations than on the energy they use.

- Advanced window systems are cost effective, but this is caused mainly by the reduction of the capacities of the climate installation causing a dramatic reduction in capital costs. It shows that the extra costs for the window systems are overcompensated by the reduced costs of the installation. Energy is also decreasing but on a modest scale.

- The emission of CO_2 of a building can be reduced with 18% by applying advanced solar protection systems when compared to the window system with uncontrolled indoor Venetian blinds. It can be further increased to 28% when night cooling with motorized windows are applied.

- The reduction of CO_2 emission of 28% in office buildings can roughly be estimated at 3% for the whole country.

- Integrated design of HVAC and facades reduces the costs dramatically. It can be concluded that in that case the extra costs for the advanced solar protection system delivers profit right away. This can not be said of the last minute solutions with capacities resulting from the worst case situation (inside Venetian blinds).

- If the manufacturers of window systems are involved in the early stage of the design then they can show their products have a pay back time of 0 years. They are profitable right from the beginning!

- If the manufacturers of window systems plays no role in the early stage of the design then it will be faced with oversized installation designs. The energy saving, that is the only positive factor then, will not convince the client when pay back times of 16 years are mentioned. If energy prices are supposed to increased with 10% per year then the pay back time for the non integrated design will be reduced to 5 years. Thus even then advanced window systems become cost effective.

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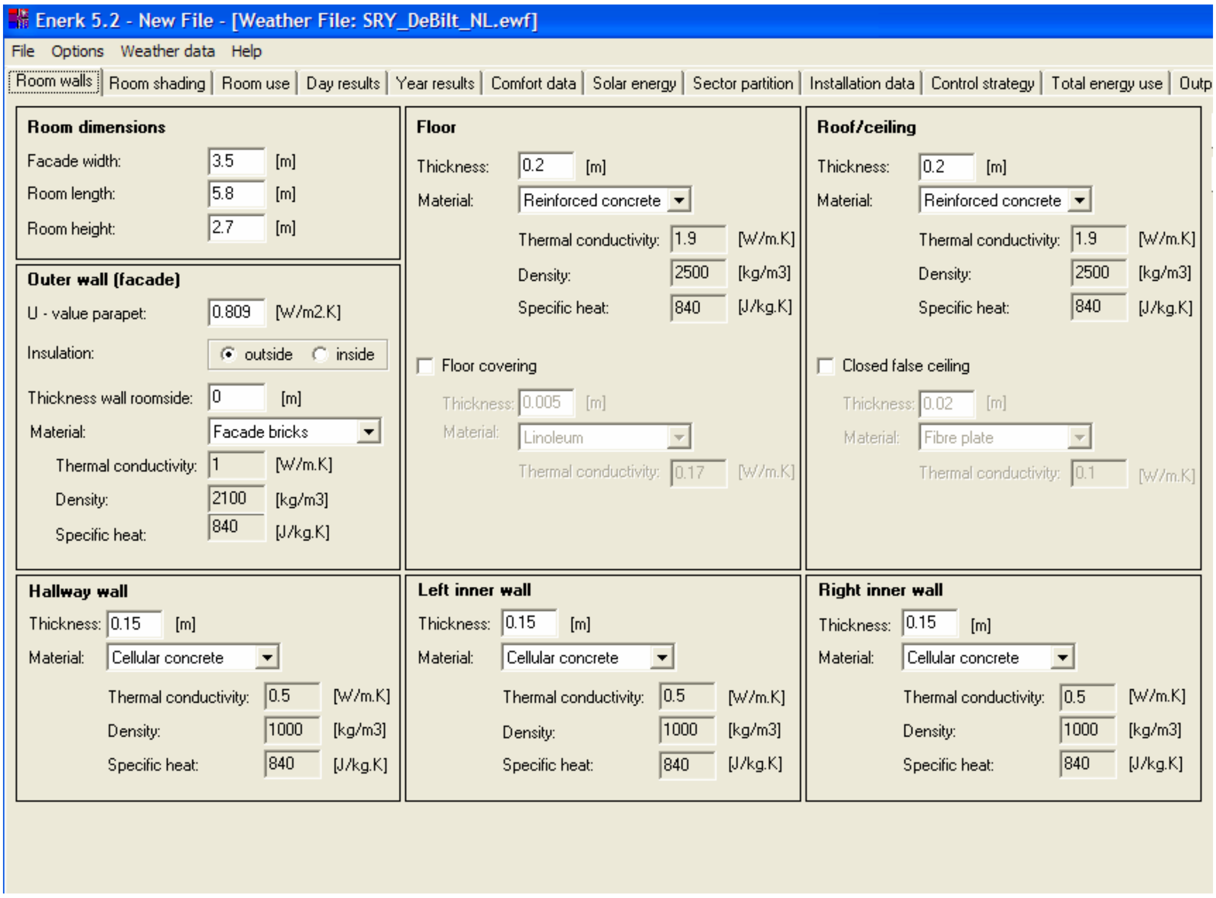
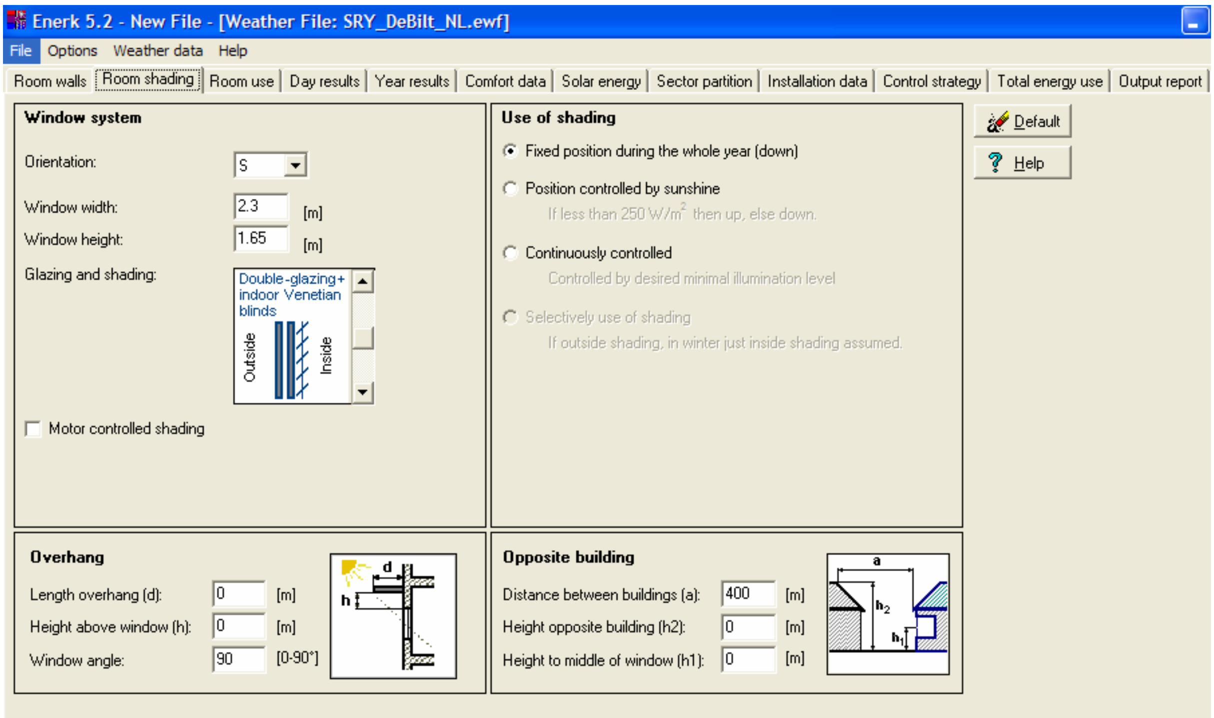
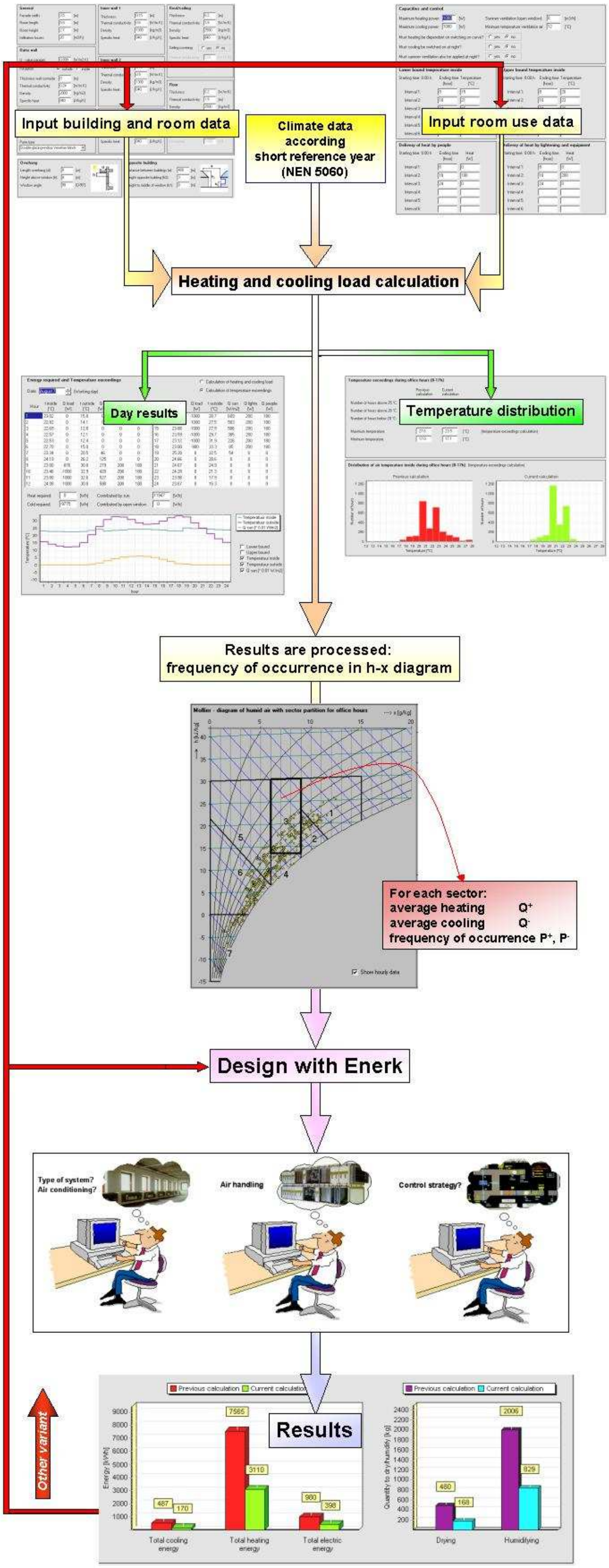
8 Appendix

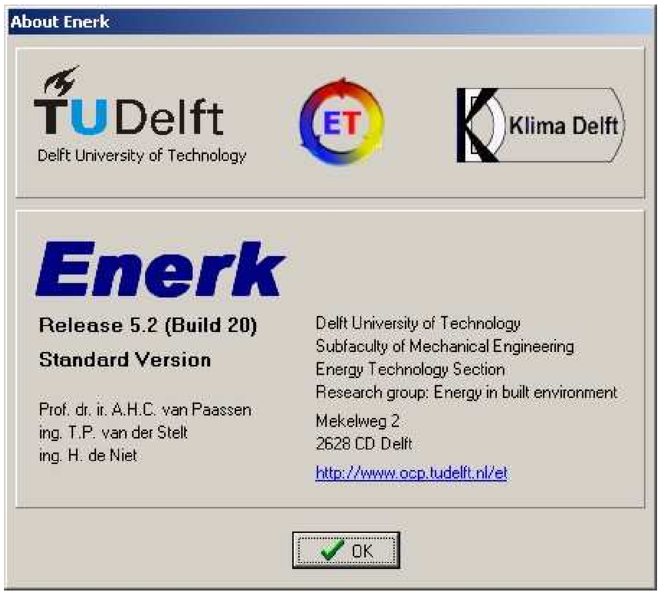
Appendix 8.1
Input data for the room and one of the shading system considered.





Appendix 8.2 Enerk





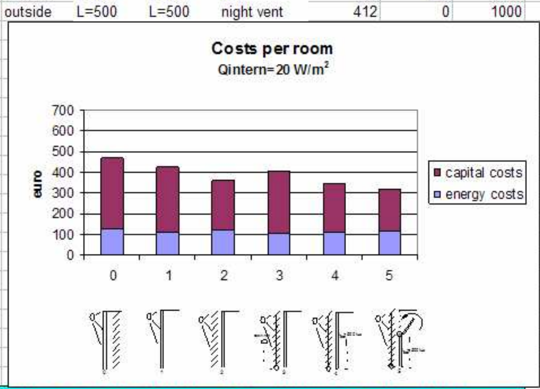
Enerk is a computer program to design HVAC systems in close connection with the façade and its solar shading devices. It can be used at the early stage of a project to make well grounded selections cut of the maze of possibilities. By the interactive approach and the help files with fundamentals it will help the designer to find the best solutions with respect to energy consumption, CO_2 and costs.

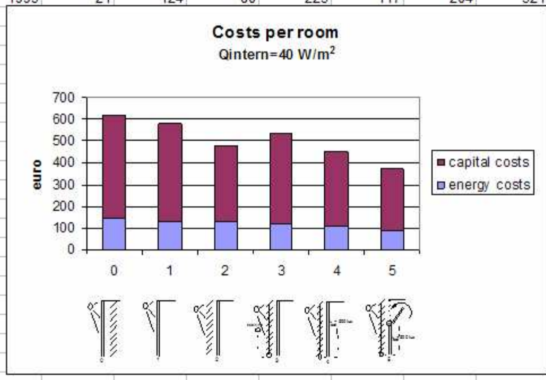
Appendix 8.3 Calculation results

Artificial lighting controlled at L=500 lux	Walls: floor/ceiling of 0.2m concrete; separation walls 0f 0.02 Gympsum board
Short reference year (de Bilt;NL)	Orientation: south; glas area= 3.8 m2 (40% of façade)
Medium heavy building	Dimension room: 5.8 X 3.5 X 2.7 m

Internal load 20W/(m2 floor): people:180; equipment:100; lighting 120 W.

					room level				Installation level					Yearly costs (euro)			CO2
code	solar protection blinds	control protection	control lighting lux	control window opening	Energy heating kWh	cooling kWh	Capacities heating W	cooling W	heating E+ kWh th	cooling E- kWh e	fan Efan kWh e	artificial lig Elighting kWh e	electricity total kWh e	energy	capital	total	kg
0	inside	no; down	L=500	no	200	670	1000	900	1484	143	119	199	461	125	347	472	471,98
1	no	no	L=500	no	175	761	1000	880	1462	172	117	69	358	111	315	426	428,44
2	outside	ever down	L=500	no	286	211	1000	300	1670	27	123	225	375	122	236	358	476,5
3	outside	Qsun>250	L=500	no	264	379	1000	540	1591	64	123	69	255	103	304	407	415,1
4	outside	L=500	L=500	no	393	119	1000	230	1878	23	124	80	226	112	232	344	461,48
5	outside	L=500	L=500	night vent	412	0	1000	0	1993	21	124	80	225	117	204	321	484,1





Internal load 40W/(m2 floor): people:180; equipment:500; lighting 120 W.

					room level				Installation level					Yearly costs (euro)			CO2
code	solar protection blinds	control protection	control lighting lux	control window opening	Energy heating kWh	cooling kWh	Capacities heating W	cooling W	E+ kWh th	E- kWh e	Efan kWh e	Elighting kWh e	electricity total kWh e	energy	capital	total	kg
0	inside	no	L=500	no	27	1696	1000	1400	1125	410	115	199	742	144	477	621	506,96
1	no	no	L=500	no	13	1742	1000	1360	1107	424	115	69	607	127	454	581	452,06
2	outside	ever down	L=500	no	39	1103	1000	780	1239	231	117	225	574	129	350	479	465,92
3	outside	Qsun>250	L=500	no	48	1310	1000	1000	1265	294	118	69	481	118	417	535	435,78
4	outside	L=500	L=500	no	60	905	1000	710	1347	182	120	80	382	109	345	454	414,56
5	outside	L=500	L=500	night vent	74	301	1000	340	1372	35	120	80	234	91	281	372	363,32

Appendix 8.4. Validation by comparison

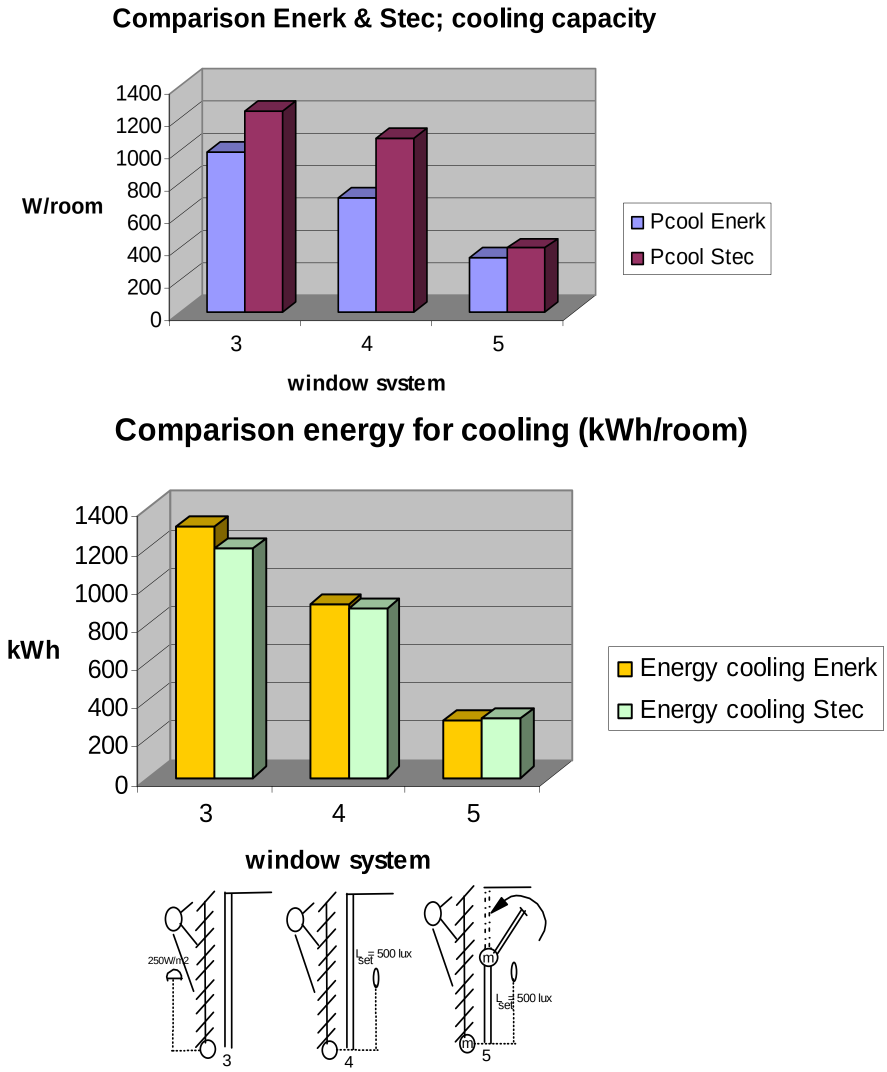


Figure A1 . Cooling load capacity and energy consumption for cooling calculated by two different programs: Enerk and Stec [PhD, Stec]

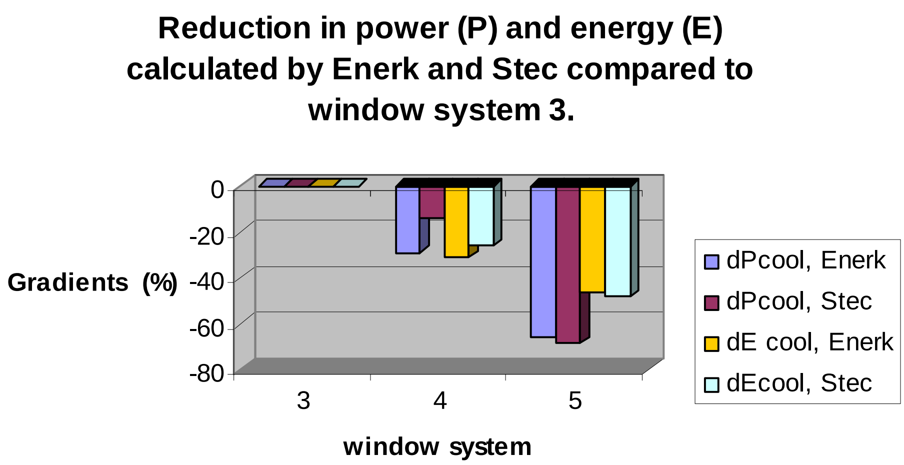


Figure A2 . Reduction in cooling load capacity and energy consumption calculated by two different programs: Enerk and Stec [PhD, Stec]. Both programs show reductions of the same order.