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Closed supermarket refrigerator and freezer cabinets: a feasibility study

F.A.T.M. Ligthart

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Acknowledgement/Preface

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Abstract

The City of Amsterdam's Environmental & Building Department commissioned the Energy research Centre of the Netherlands (ECN) to calculate the time needed to recoup the cost of closing the existing refrigerator and freezer display cabinets used in supermarkets. We were asked to give particular consideration to the following aspects;

1. The cabinet's energy consumption
2. The energy price
3. The cost of closing the cabinet

The payback period has been calculated by dividing the investment required to close the cabinet by the amount saved on energy each year, less any additional costs incurred as a result of the scheme.

For existing upright refrigerator cabinets, that period works out at 2.9 years with a margin of error of ±0.9 years. In the case of chest freezers, it is approximately 2.4 years, with a maximum of 2.5 and a minimum of 1.3 years. For chest refrigerators, the payback period is 9.4 years. If units are closed overnight only, the time needed to payback the cost of that measure ranges between 1.8 and 4.1 years.

Moreover, research shows that closing refrigerator and freezer display units will not reduce turnover. In addition, it will significantly improve the ambient climate in supermarkets.

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1. Introduction

At the average Dutch supermarket, refrigeration and freezing account for no less than 62 % of electricity consumption. A large supermarket consumes ten times as much energy as an office of the same size (source: *Cijfers & tabellen*, Novem).

There was good reason, then, for the conclusion of a specific voluntary arrangement on this matter with the industry: the Long-Term Energy Saving Agreement for Supermarkets (Meerjarenafspraak Energiebesparing Supermarkten, MJA), signed in 1999. In that agreement, the sector promised to use approximately 32 % less energy in 2010, compared with the 1995 figures. By 2004, however, it had become clear that the industry was doing far too little to reach that target. At that point, it had achieved savings of just 4.7 %.

In response, the City of Amsterdam's Environmental & Building Department and the IJmond Regional Environmental Service decided to launch a project entitled "Supermarket enforcement – an open door" ("Handhaven bij supermarkten – een open deur"). Based upon the standards defined in the Environmental Management Act (Wet milieubeheer, Wm), this would review whether the supermarkets were actually taking all the agreed measures with a payback period of five years or less.

RESULT	
Energy consumption in monitoring	3583 PJ (1995) and 9557 PJ (2004)
Sector-wide energy consumption	11.8 PJ (1995) and 12.7 PJ (2004)
MJA1 target	32 % improvement in energy efficiency 5 % more sustainable energy in 2010, compared with 1995
Result in 2004	1.8 % overall improvement in energy efficiency
Result for 1995-2004	4.7 % overall improvement in energy efficiency

Figure 1.1 *MJA: summary of status (source: Novem)*

1.1 The project: “Supermarket enforcement – an open door”

This project has achieved considerable energy savings. And if it were to be followed up on large scale at the national and European levels, the potential savings are spectacular.

Almost two-thirds of a supermarket's energy consumption is accounted for by the refrigeration and freezing of the products on sale. And these stores' absolute consumption figures are also high: most use 300-500 MWh of power a year. There is one supermarket in Amsterdam which consumes 1300 MWh (1.3 million kWh). Yet simply by fitting doors to the refrigerated display cabinets, savings of 40-55 % could be achieved on the energy used for cooling. The potential savings are summarised in the table below.

Table 1.1 *Potential savings for supermarkets*

Annual saving	kWh	Equivalent to the energy consumption of…
Per supermarket	127,000	42 households
All 170 supermarkets in the project	22,860,000	7,620 households
All supermarkets in the Netherlands	520,000,000	173,500 households

The savings recorded at the 170 stores covered by the project are equivalent to the energy consumption of approximately 7,500 households. Were this effect to be reproduced on the European scale, the results would be truly impressive: some 10 billion kWh would be saved each year, the amount of electricity used by 3.1 million households. To put that into perspective, there are approximately 6 million households in the Netherlands.

Moreover, this project is highly reproducible. In terms of their configuration, product range and use of technology, supermarkets in the Netherlands and elsewhere have much in common. Indeed, many chains have branches in several European countries. If all supermarkets were to introduce daytime closure of their refrigerators and freezers, all would incur similar investment and operating costs. There would thus be a "level playing field" with no distortion of competition. In other words, once the industry in one region accepted the project – voluntarily or by compulsion – then it would very soon be adopted by others in the country concerned.

When taking steps to save energy, those measures which cost very little or no money are obviously most likely to be adopted first. Further moves are increasingly expensive and difficult to implement, particularly when bearing in mind the potential returns. This fact makes it all the more worrying that the level of energy savings currently achieved remains so far short of the target set for 2010: 4.7 % now compared with the intended 32 %. If refrigerators and freezers are not closed, there is a very good chance that a whole range of other measures – quite possibly with payback periods longer than five years – will have to be taken at the last minute in order to achieve the target saving on time. In this light, closure is an ideal solution because it does not involve expensive investments and yet could easily achieve the saving of 32 % promised by the supermarkets in the MJA.

1.2 The ECN assignment

The City of Amsterdam's Environmental & Building Department commissioned the Energy research Centre of the Netherlands (ECN) to calculate the time needed to payback the cost of closing the existing refrigerator and freezer display cabinets used in supermarkets. We were asked to give particular consideration to the following aspects.

1. The cabinet's energy consumption
2. The energy price
3. The cost of closing the cabinet

The payback period has been calculated by dividing the investment required to close the cabinet by the amount saved on energy each year, less any additional costs incurred as a result of the scheme.

This report discusses two kinds of display units.

- Upright refrigerated cabinets
- Chest freezers and refrigerators

2. Closing upright refrigerated cabinets: calculation basis for the payback period

This chapter covers upright refrigerated display cabinets.

Figure 2.1 *Upright refrigerated display cabinets*

In calculating the payback period for the closure of these units, the following factors were taken into account:

1. The cabinet's energy consumption.
2. The saving achieved by closing the cabinet.
3. The saving achieved by overnight closure, which is already widespread. This has to be deducted from the figure from round-the-clock closure, otherwise that saving would be counted twice.
4. The energy price.
5. The increased cost of heating the store to offset cooling caused by the "leakage" of cold air from refrigerated display cabinets.
6. Additional costs, such as maintenance of the doors. Cleaning costs are not considered, since not enough is known about them. Loss of turnover is also taken into account.
7. The price of the doors or panels used to close the unit.

2.1 Upright refrigerated cabinets: energy consumption

According to the Eurovent Certification Database as of October 2005,[1] the average energy use of upright refrigerated display cabinets is approximately 20 kilowatt hours per frontage metre per day (kWh/m/d). Since it is derived from numerous measurements taken both at test facilities

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[1] http://www.eurovent-certification.com/en/Programmes/Characteristics.php?rub=02&srub=01&ssrub=&lg=en&select_prog=RDC. Power consumption figures listed here are between 17 and 23 kWh per frontage metre per day.

and in actual supermarkets, this value can be considered reliable for this type of unit and so is used as the basis for our calculations. There are other possible sources for this reference value, including simulation models such as EKS and Stimec laboratory measurements; in the next section, however, we explain why these are regarded as less reliable for the purposes of practical research.

2.1.1 Theoretical approaches

he EKS ("Energieberekening Koeling Supermarkt":[2] supermarket cooling energy calculation) simulation programme is a tool used to compare the energy consumption of various refrigerator and freezer units under different circumstances. Its user guidelines clearly state that actual consumption must be established by taking measurements and it is for this reason that we have not used it to determine the average energy consumption of the units under consideration here.

The so-called Stimec ("stimulation of efficient commercial cooling"[3]) measurement, which is also used regularly and is derived from the Eurovent Certification Database, is generally taken under laboratory conditions rather than in everyday usage situations. Consequently, it is not an accurate reflection of energy consumption on the actual retail floor and so has not been used here.

2.1.2 Practical values

In the various practical studies on the subject, there appears to be consensus concerning the amount of energy which can be saved by closing upright refrigerated cabinets. The figure we have used in our calculations, 55 %, is an average of numerous values measured at different locations. Appendix D explains how that figure was arrived at. There is no further discussion of the matter in this report.

The reason why this study attaches so much value to practical measurements rather theoretical calculations, simulations or laboratory tests is that the conditions in actual retail situations are very different from those in test environments. Below we describe a number of those situations, which are difficult to replicate under test conditions at a research facility but nevertheless have a negative impact upon the energy consumption of open refrigerators and freezers in retail settings.

1. The air in and around the units is in constant motion as a result of people walking past and shoppers picking up products. In the case of an upright cabinet, for example, this means that the curtain of air is being disrupted almost all the time and so its effect is lost.
2. Products often wholly or partially block the vents producing the curtain of air, or are positioned in the air stream. This negates much of its effect, and in some cases even diverts the flow of cold air directly into the shop.
3. In actual shop situations, the constant flow of products in and out of the display cabinets often means that their doors are left open for extended period. This causes a constant movement of air past the units, resulting in cold being lost.
4. The number of people in a supermarket can make the air inside quite humid, particularly when it is raining and shoppers come in wearing wet coats. That humid air mixes with the cold air in the refrigerators and freezers to increase the amount of

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2 http://www.tno.nl/bouw_en_ondergrond/bouwinnovatie/koudetechniek_en_warmtepo/koelsystemen_voor_superma/supermarket_energy_consum/index.xml

3 http://www.tno.nl/bouw_en_ondergrond/bouwinnovatie/koudetechniek_en_warmtepo/koelsystemen_voor_superma/the_stimeck_list/

condensation on their evaporators, causing them to consume more energy. Condensation forming on the displayed products also make them less attractive.

5. Air contaminated by in-store activities as described in Appendix A flows past the evaporators in large volumes, depositing dirt on them. Only immediately after cleaning do the evaporators work at maximum efficiency. The condenser, too, becomes dirty and so its performance declines steadily.
6. Filling and cleaning the cabinets increases energy consumption.

For all these reasons, the actual energy consumption of refrigerators and freezers can be considerably higher in practice than under laboratory conditions.

2.1.3 Energy consumption

A refrigerator cabinet's energy consumption figure is based upon the average value recorded in the Eurovent Certification Database. To establish the payback period as conservatively as possible, two other cases with consumption figures lower than the average practical value have also been used. The three cases are:

1. The average figures for equipment of this kind from the Eurovent Certification Database
2. The minimum energy consumption figures for various types of upright refrigerated display cabinets as listed in the Eurovent Certification Database
3. A specific case from a major supermarket chain (in the Netherlands) which uses very low-energy equipment

2.2 Savings

Opinions concerning the savings achievable from closure are fairly consistent. Appendix D explains how the figure of 55 % has been arrived at.

2.3 Overnight closure

Overnight closure has for years been standard supermarket practice, since it is a simple and cheap measure with a short payback period. For that reason, too, it is no longer included in the Energy Investment Tax Allowance (Energie-investeringsaftrek, EIA) scheme for businesses. The covers used work like roller blinds and can be either manually or mechanically operated. The material involved is generally a polyester fabric with a reflective metallic coating. The "blinds" are lowered after closing time to isolate the cold air inside the refrigerated unit from the relatively warm atmosphere in the rest of the store. The material used prevents the exchange of heat by convection, and to a certain extent also radiation and transmission. The figures for overnight closure are given in Chapter 4; those relevant to upright refrigerated display cabinets are used below.

2.4 Energy prices

The energy prices given in the feasibility calculations vary between supermarket chains, in the range of 8.0-10.5 eurocents per kWh. The value actually used is the average price for a large chain, which works out at 8.8 eurocents per kWh. In alphabetical order, the concerns supplying data for these calculations are Albert Heijn, Lidl and Schuitema.

According to the ECN policy studies prepared for the Ministry of Economic Affairs, the energy price has increased at an average annual rate of 4 % over the past five years. This rate is expected to be maintained for some years to come. Because the increase is higher than inflation, it will probably have a shortening effect upon payback periods over the next few years.

2.5 Heating costs

The "leakage" of cold air from refrigerators and freezers tends to cool a store. In most cases, the heat extracted from that equipment is channelled outside through the refrigeration unit and the condenser on the roof. The store's heating system therefore has to replenish it, which means that it works harder than if the refrigerators and freezers were not installed. We count the reduction in heating costs as a result of covering refrigerator cabinets as an additional energy saving (Appendix E). But any contribution made by those cabinets towards cooling the store is not counted because it plays no part in achieving a pleasant ambient temperature in the same way as a specially designed cooling system does (see Appendix C).

2.6 Additional costs

The additional stocking and maintenance times for the display cabinets are taken from TNO report 2006-A-R0054/B and Van Beek report 725 (definitive version 1.0, 28 April 2004). The additional costs of cleaning are discussed in Appendix A.

Appendix B addresses the issue of reduced turnover. Based upon the arguments presented there, no figure for loss of turnover is included in the calculation of the payback period for closure.

2.7 Cost of closure

The cost of actually closing the cabinets, including installation and synchronisation, has been arrived at by taking the average of the prices actually paid for these services in the open market. There are also suppliers which charge two to three times this amount, though. Every business is free to choose more expensive doors if they wish, but this study is based upon those which satisfy the standard requirements in terms of insulation value, sealing, safety, usability, mechanism life and so on.

2.7.1 Doors

With one exception, there is not much difference between the prices of the doors listed here. The calculation is based upon the average of the four prices quoted. The letter in the first column is that used to represent the average door price in the formula at the end of this report.

D	Door price[4] (€/m)	596	622	1,142	705	Average:	766

All the figures and values quoted in this report are anonymised. In other words, ECN knows who supplied them or at which company measurements were taken – and they are named in acknowledgement of their contribution to the study – but we have chosen not to link specific data to its provider. This approach precludes any commercial advantage or disadvantage accruing to the companies concerned, whilst still allowing other firms to acquaint themselves with these cost-saving measures through the report's publication.

2.8 Closing upright refrigerated cabinets: payback period

The content of the previous sections is supported below by examples and payback period calculations.

2.8.1 Payback period

The payback period is calculated in Appendix F. That includes a summary of the energy consumption figures for display cabinets in a variety of situations: open, overnight closure, gas sav-

[4] Prices include installation, modifications to the display cabinets and synchronisation, but exclude Energy Investment Tax Allowance (EIA). They were quoted by the following suppliers, listed here in alphabetical order: Smeva, Tahob, Van Beek and Veld.

ings with daytime closure and other savings and costs. The payback period is arrived at by dividing the investment in doors by the average power saving in kWh plus the gas saving, less the costs of maintenance and additional stocking time. In concise form, the formula is: T = D/B.

B, the total recoupable amount per year, is:	Case 1	Case 2	Case 3
B Net power saving plus gas saving, after deductions for previous overnight closure, maintenance and additional stocking time (in euros).	379	257	193
T Payback period (in years).	2.0	2.9	3.8

See Appendix F for full details.

2.8.2 Payback period: new buildings

The amount of cooling power needed falls by an estimated 20 %, at least, as a result of cabinet closure – a figure which seems justified, given the average saving of 50 % – which means that installed capacity of the electrical system can be reduced. This factor is particularly relevant in the case of new or refurbished supermarket branches and, when taken into account, can actually result in a negative payback period. In other words, covering the cabinets is cheaper than leaving them open from the moment the store starts doing business, since the cost of installing a power supply with a greater capacity or a larger transformer, say, would have been many times that of fitting the doors. Moreover, the cooling systems are cheaper because they are of lower power.

2.8.3 Conclusion

A payback period has been calculated based upon the criteria described above and the additional aspects covered in Appendices A-E. For the closure of upright refrigeration cabinets, that period is 2.9 years with a margin of error of ±0.9 years.

When a new supermarket is built or an existing one is refurbished, the payback period will often actually be negative because less investment is needed in power or transformer capacity. With about 20 % less need for power, the cooling equipment is also cheaper.

3. Daytime closure of chest freezers: calculation

This chapter covers chest freezer display units of the kind illustrated below:

Figure 3.1 *Chest freezer*

To establish the payback period for the closure of these units, the same method has been used as with upright refrigerated display cabinets. The values concerned are summarised below:

Chest freezers					Average
Door price[5] (€/m²)	271	366		211	282
	Case 1	Case 2	Case 3	Case 4	
Energy consumption[6] (kWh/m²/d)	13.0	13.0	13.0	11.7	
Saving from closure (%)	52	40	40	40	
Saving from closure (kWh/m²/d)	6.76	5.20	5.20	4.67	
Less: overnight closure (kWh/m²/d)	2.34	2.34	2.34	2.10	
Gas saving[7] (kWh/m²/d)	0.11	0.09	0.09	0.08	
Energy price (€/kWh)	0.11	0.088	0.08	0.088	
Maintenance and additional stocking time[8] (€/m²/d)	0	0	0	0	
Payback period (years)	1.3	2.3	2.4	2.5	

Conclusion:
In the case of chest freezers, the payback period for daytime closure is about 2.4 years, with a maximum of 2.5 and a minimum of 1.3 years.

[5] Quoted by the following suppliers, listed here in alphabetical order: Deen, Dirk van den Broek, MGB Zurich and Smeva
[6] Source: Eurovent Certification Database
[7] Calculated from cold supply at a gas price of € 0.25
[8] See Appendix A

4. Daytime closure of chest refrigerators: calculation

This chapter covers chest refrigerator display units, which closely resemble chest freezer display units.

To establish the payback period for the closure of these units, the same method has been used as with upright refrigerated display cabinets. The values concerned are summarised below:

Chest refrigerators	
Door price (€/m^2)	274
Energy consumption[9] (kWh/m^2/d)	6.0
Saving from closure (%)	17
Saving from closure (kWh/m^2/d)	1.04
Less: overnight closure (kWh/m^2/d)	0.36
Gas saving[10] (kWh/m^2/d)	0.02
Energy price (€/kWh)	0.088
Maintenance and additional stocking time[11] (€/m^2/d))	0
Payback period (years)	9.4

Conclusion:
For chest refrigerators, the payback period is 9.4 years.

[9] Source: Eurovent Certification Database
[10] Calculated from cold supply at a gas price of € 0.25
[11] See Appendix A

5. Overnight closure

Overnight closure has for years been standard supermarket practice, since it is a simple and cheap measure with a short payback period. For that reason, too, it is no longer included in the Energy Investment Tax Allowance (Energie-investeringsaftrek, EIA) scheme for businesses.

Figure 5.1 *“Roller blind”-type screen for overnight closure*

These screens work like roller blinds and can be either manually or mechanically operated. The material involved is generally a polyester fabric with a reflective metallic coating. The screens are lowered after closing time to isolate the cold air inside the refrigerated unit from the relatively warm atmosphere in the rest of the store. This prevents the exchange of heat by convection, and to a certain extent also radiation and transmission. The table below shows the energy and payback data for a supermarket's upright display cabinets:

Upright refrigerated display cabinet	
Cost of motorised overnight cover (€/m)	124
Saving from closure (kWh/m/d)	2.12
Energy price (€/kWh)	0.088
Payback period (years)	1.8

Chest cabinets are also covered at night, but their shape and configuration make this very easy: a couple of perspex panels or a roll of foil is enough. The costs of these are negligible, although the resulting energy savings are not. One major supermarket chain investigated this and calculated the saving at 18.1 %.

In the report *Energiebesparing buiten de verbouwing om* ("Energy savings without rebuilding"), Van Beek puts the savings achieved by overnight closure at 20 % and the investment required at € 100 per metre. From this, Van Beek arrives at a payback period of 4.1 years.

In its report, *Energiebesparing door nachtafdekking, praktijkmeting bij een supermarktfiliaal* ("Energy savings from overnight closure – practical measurements at a supermarket branch"), TNO calculates a average saving[12] of 1.8 kWh/m/d for all kinds of refrigerated and freezer display units.

Conclusion:
The payback period for overnight closure ranges between 1.8 and 4.1 years. And the saving achieved is approximately 2 kWh/m/d.

[12] Conclusion of report R 91/294, p. 11

6. General conclusion

For existing upright refrigeration cabinets, the payback period works out at 2.9 years with a margin of error of ±0.9 years.

In the case of chest freezers, it is approximately 2.4 years, with a maximum of 2.5 and a minimum of 1.3 years.

For chest refrigerators, the payback period is 9.4 years.

If units are closed overnight only, the time needed to payback the cost of that measure ranges between 1.8 and 4.1 years.

When a new supermarket is built or an existing one is refurbished, the payback period will often actually be negative because less investment is needed in power or transformer capacity. With about 20 % less need for power, the cooling equipment is also cheaper.

Appendix A Costs of cleaning and filling display units

Many calculations incorporate additional costs for cleaning the glass panels used to close vertical refrigeration units. All, however, neglect to mention one important cost saving. Throughout the day, an open unit is subjected to a constant barrage of dust, vermin and organic material deposited by the people visiting the store. As a result, it needs to be cleaned far more thoroughly than is the case with a closed cabinet. Under HACCP procedures, all display units have to be cleaned according to a regular schedule. But the dirtier they are, the longer that takes for each. Yet the costs saved by the need to clean closed units less intensively are reflected nowhere in the calculations. We have therefore omitted the cost of cleaning the new doors from our calculations, since it needs to be offset against a potential saving about which no reliable data is available. Further research is required to establish whether the net cost of cleaning a closed display cabinet is higher or lower than that for an open one. Whatever the case, the additional costs are compensated for – at least in part – by the benefits gained.[13]

As far as cleaning is concerned, much the same applies to chest freezers and refrigerators. But there is also another factor to consider here: covering a chest unit actually makes it easier to replenish. In practice, staff place products on the cover as they are filling the cabinet since this is more convenient than transferring them directly from a trolley on the floor. In any case, a display chest is always easier to fill because articles are simply stacked on the bottom whereas an upright cabinet has a series of shelves to fill. For these reasons, we have omitted any figure for the cost of additional stocking time from our calculation of the payback period of chest freezers and refrigerators.

[13] Reported by MGB Logistik-TA Zurich. This Swiss body is a similar to a national standards institute, but specifically for this kind of equipment.

Appendix B Effect upon turnover

The TNO report *Covering of freezer units with glass panels* (TNO 93-340, September 1993) reveals that such covering has no demonstrable effect upon turnover. MGB Logistik-TA Zurich has also come to the same conclusion.

The risk of items on display failing food safety inspections has not been included in the calculations. That risk is actually considerably higher for open refrigerated cabinets, because of the greater temperature fluctuations within them.[14]

[14] Reported by MGB Logistik-TA Zurich

Appendix C Ambient climate around open refrigeration units

The ambient climate inside a supermarket is directly influenced by the energy consumed for cooling and heating within it. For that reason, we have also investigated this aspect in theory – and also, to a certain extent, in practice. Our finding is that the climate in the vicinity of open refrigerated display cabinets does not comply with the applicable health, safety and similar standards. Those standards govern the following values:

1. Air temperature
2. Rate of air circulation
3. Atmospheric humidity
4. Temperature of exposed surfaces

The limits for all of these factors are breached for open refrigerated cabinets.

<u>1. Air temperature</u>

The temperature inside the store is usually maintained at a constant level of about 21 degrees Celsius, a fact several branch managers have confirmed by telephone. In the vicinity of open refrigerated cabinets, however, air at this temperature mixes freely with that produced by those units. Depending upon their type, the temperature of that air is ranges between 4 and 7 degrees Celsius. The extent of the mixing depends upon the situation, as described in section 2.1.2. The result is that the air in this area can measure anything between 4 and 21 degrees, and that temperature can change by the minute. According to the energy figures, the amount of mixing is approximately 55 %, which gives us an average ambient temperature of 15.5 degrees Celsius. According to the graph in ASHRAE standard 55-74, for a comfortable interior environment the temperature should not drop below 20 degrees. It is clear, then, that the air close to open refrigerated cabinets falls well short of this requirement.

<u>2. Air circulation</u>

To prevent unpleasant draughts, the air inside the building should circulate at a rate of no more than 0.15 m/s. Given the difference in temperature between the air emerging from open refrigerated cabinets and the ambient 21 degrees Celsius, it can be demonstrated mathematically that that rate is being considerably exceeded. Moreover, our actual measurements have confirmed this.

<u>3. Humidity</u>

A psychrometric chart reveals that the humidity of air warmed from 7 to 21 degrees Celsius falls by an absolute figure in excess of 50 %. This means that the humidity of the air in the vicinity of open refrigerator cabinets can drop to as low as 20 % when the ambient humidity is 70 %, a common value. At 20 % humidity, many people experience problems such as dehydrated mucous membranes in the respiratory tract, which increase their risk of contracting infections.

<u>4. Surface temperatures</u>

The interior surfaces of a refrigerated cabinet and the products it contains are at about the same temperature as the air inside – that is, between 4 and 7 degrees Celsius. This is therefore the temperature they radiate. By comparison, a comfortable ambient temperature in an office where the walls have cooled to 17 degrees Celsius over the weekend can be restored by turning up the air temperature to 23 degrees on Monday morning: the one offsets the other. But if the difference is too great, this method does not work. There is "summation" instead of "compensation":

the negative effect of too low an air temperature compounds the negative effect of the radiating cold. The discomfort caused by draughts can also be offset by heating the air more – but here, too, from a certain point the opposite happens. The overall result is a combination of factors which create a rather unpleasant climate where people do not wish to remain any longer than is absolutely necessary.

Cooling for comfort

For the same reasons as described above, the cooling effect of the equipment in the chilled and frozen food section of a supermarket does not meet acceptable standards for dedicated interior cooling systems.[15]

The best way of improving the climate inside supermarkets, then, is to close the refrigerator and freezer cabinets and, evenly throughout the space, to introduce relatively cool air close to the ceiling and allow it to mix with the air already inside the building. This will maintain a constant and even interior temperature of 21 to 25 degrees Celsius in the summer, the exact level depending upon the outside temperature.

[15] Reported by MGB Logistik-TA Zurich

Appendix D Closing upright refrigerated display cabinets: average efficiency improvement

The table below shows the efficiency improvements gained from closing upright refrigerated display cabinets, as reported in various studies on this topic.

Table 2: Closure of upright refrigerated display cabinets: efficiency improvements

Table 1: Closure of upright refrigerated display cabinets: efficiency improvements

Reporting body	Report efficiency improvement (%)
Van Beek	55
TNO	55
Eurovent[16]	50
AGM (Switzerland)	86

From the above, it can be seen that 55 % is a conservative average of the reported efficiency improvements.

[16] Eurovent is a European association for the air-conditioning and refrigeration equipment industry. Its performance testing is carried out by independent laboratories under contract to Eurovent.

Appendix E Heating losses, store cooling

The increase in heating costs is calculated by assuming that the loss of cold from the display cabinets during that period of the year when heating is required is the same as the loss of heat. In this way, it is known how much additional heat must be supplied. That amount is then converted into the quantity of natural gas needed to provide it. The calculations are based upon a heating system with an overall efficiency of 80 % and a gas price of € 0.25 per cubic metre.

Sample calculation using the figures from Appendix F:

The power consumption of 20 kWh per frontage metre per day is multiplied by the saving, or "cold loss", of 55 %. That cold has to be heated by a central heating system with an overall efficiency of approximately 80 %. The amount of heat required, which is equal to the cold loss divided by the efficiency of the heating system, reveals how much power (kWh per metre per day) that system has to supply during the period when heating is needed. In this case, we have assumed that that is six months of the year. Ten kilowatt hours is approximately equal to 1 cubic metre of natural gas, the price of which we have taken as € 0.25. The factor of three found in the formula is the cooling unit's coefficient of performance – in other words, for every kWh of power, three kWh of cold is produced. It is assumed that the store is open during 36 % of the week (10 hours a day, six days a week) and that it is not heated when closed. But it is still cooled at those times. This, therefore, is a fairly conservative calculation.

The heating costs saved are:
20 x 0.55 x 3 x 0.5 x 0.36 / 0.8 / 10 x 0.25 = € 0.18 per metre per day.

Appendix F Closure of upright refrigerated display cabinets: detailed sample calculations

The letters used in the formula are those from the first column of the table. "D" represents the average market price of the doors; "T" is the payback period.

T = price of daytime closure / [(energy saving from daytime closure + additional saving) - additional costs]

$$T = D / ([(V \times C - N) \times F + E - G] \times 365)$$

In the tables below, the most favourable combination of costs and yields is shown in the left-hand column and the least favourable in the right-hand column.

Energy

	See notes for descriptions of cases	Case 1	Case 2	Case 3	See note
V	Energy consumption (kWh/m/d)	20[17]	17	14.3[18]	
C	Saving from closure (%)	55	55	55	[19]
N	Less: overnight closure (kWh/m/d)	2.1	1.8	1.5	[20]
E	Gas saving (€/m/d)	0.18	0.15	0.13	

Energy price

	Energy price[21] (€/kWh)			
F	Variation in energy price between stores	0.11	0.088	0.08

Additional costs

F	Additional maintenance[22] (€/m/d)	0.08	0.08	0.08

See next page for the rest of the calculation.

[17] Interpretation of various figures, in accordance with the Eurovent Certification Database
[18] A specific case of a major supermarket chain using very low-energy equipment
[19] Average of measurements taken in practice and by research institutes
[20] Result of measurements taken in practice, as reported in Chapter 4
[21] ECN-C--06-012.
[22] Cleaning costs are not included here because they are unclear and could be either higher or lower. See Appendix A.

We shall now call the denominator "B".

$$B = [(V \times C - N) \times F + E - G] \times 365$$

So the payback period is now: T = D / B.

	B, the total recoupable amount per year, is:	Case 1	Case 2	Case 3
B	Net power saving plus gas saving, after deductions for previous overnight closure, maintenance and additional stocking time (in euros).	379	257	193

T	**Payback period in years**	**2.0**	**2.9**	**3.8**