TNO Institute of Environmental Sciences,
Energy Research and Process Innovation

Laan van Westenenk 501
P.O. Box 342
NL-7300 AH Apeldoorn
The Netherlands

Telex 36395 tnoap nl
Phone +31 55 549 34 93
Fax +31 55 541 98 37

TNO-report

Energy labelling of supermarket refrigerated cabinets

Final report

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Authors
F. Elefsen
Danish Technological Institute
Aarhus, Denmark

A. Gigiel
University of Bristol, FRPERC
Bristol, UK

D. Maimann
Danish Energy Agency
Copenhagen, Denmark

S.M. van der Sluis
TNO Institute of Environmental and
Energy Technology (coordinator)

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Executive summary

Under the EC SAVE programme, a proposal for the energy labelling of refrigerated display cabinets is being prepared. An energy label should give users information on the energy efficiencies of cabinets in a comparable way. In this way, the user can make an energy conscious choice when purchasing a new cabinet, and manufacturers may strive to produce more efficient cabinets.

Former attempts

Until this date, there are no existing labelling schemes for refrigerated display cabinets. An attempt made in The Netherlands some 10 years ago (the 'energy indicator') was abandoned mainly because:

- it was felt that The Netherlands could not influence the - European - market;
- the energy indicator included severe quality (temperature) requirements on cabinets;
- it was feared that the testing costs would be too high.

In the current labelling proposal, the setup will be chosen in such a way as to circumvent the above-mentioned objections as far as possible.

Categorisation

Cabinets are categorized according to the service rendered to the user, so that a more or less free choice of models exists within the bounds of each category. The following categories (with category numbers) have been defined:

00. combination cabinets for frozen and chilled products

10 chilled, others	20 frozen, others
11 chilled, open top	21 frozen, open top/glass top
12 chilled, service counter	22 frozen, service counter
13 chilled, island site	23 frozen, island site
14 chilled, multi deck	24 frozen, multi deck
15 chilled, graduated	25 frozen, graduated
16 chilled, glass door	26 frozen, glass door
17 chilled, roll-in	27 frozen, roll-in

Each category is furthermore divided into 'Integral cabinets' (containing their own refrigerating system) and 'Remote cabinets' (to be connected to a remote refrigeration system).

The representative model

Many models of refrigerated display cabinets are being produced, often in small series (or even tailor made), and often with only slight differences between models. To measure the energy consumption for each model would lead to high testing costs. Therefore it is made possible to represent models that differ only slightly by one representative model. The use of representative models is not compulsory.

Differences between models, that may be covered by one representative model, are the following:
- temperature level;
- length;
- cosmetic differences on the exterior;
- shelve angle (flat or angled), except when shelve angle is higher than representative;
- lighting, except when lighting wattage inside cabinet is higher than representative;
- number of shelves, except when number is less than representative;
- single or multi layered glass panels, except when the number of layers is less;
- front opening height, except when this height is larger;
- front glass setup, only when not fitted on the representative model;
- glass setup for island cabinets, only when not fitted on representative model
- screen or canopy, only when screen or canopy is larger than representative.

Energy consumption measurement method

For integrated cabinets, the energy consumption in kWh/day is measured according to the European standard EN 441 - 9.

For remote cabinets, the energy consumption of electrical consumers (excluding condensing unit) is measured according to EN 441 - 9.

For remote cabinets, the heat extraction rate is measured according to prEN 441 - 12. The total energy consumption for remote cabinets (E) is calculated as if they were connected to an imaginary 'standard' refrigeration system using a standard Carnot efficiency η_{carnot}. For direct expansion systems this leads to:

$$E = E_{cab} + 24 * \phi_o / \{\eta_{carnot} * T_o / (T_c - T_o)\}$$

For remote cabinets with indirect cooling (secondary refrigerating circuit), the total energy consumption E in kWh/day is calculated as:

$$E = E_{cab} + E_{pump} + (24 * \phi_o + E_{pump}) / \{\eta_{carnot} * T_o / (T_c - T_o)\}$$

with

$$E_{pump} = 0.001 * \tau * \{q_m * v_3 * 2.5 * (P_o - P_i)\} / 0.5$$

and

$$T_o = \Theta_i - 3\ K$$

The values of η_{carnot} (0.34) and T_c (35 °C) are prescribed as is the value for τ (18 hours; or 19 hours for hot brine defrost); all other values are measured under prEN 441-12.
It can be proven mathematically that the 'ranking order' in terms of efficiency of cabinets does not change when using an actual refrigeration plant instead of the standard plant. When cabinet A is more efficient than cabinet B when using the standard plant, it is also more efficient than cabinet B on any other actual refrigeration plant.

Functionality

The basis for comparison is the 'functionality' of a refrigerated cabinet, which is used to express the 'service rendered to the user', but also plays a role in the comparison of cabinets working at (slightly) differing product temperatures. The functionality (F) is a straightforward function of size (S) and temperature difference between ambient and average product temperature ΔT:

$$F = S * (c_1 + c_2 . \Delta T / \Delta T_r)$$

The values of parameters c_1, c_2 and ΔT_r (reference temperature difference) are given for each category.
By means of a sensitivity analysis on actual cabinet data it has been shown that the 'ranking order' in terms of efficiency of cabinets does not change for a wide range of choices for c_1 and c_2 values.

Classification

When plotting energy consumption against functionality for a number of cabinets in one category, a 'cloud of points' arises, through which a 'market average' line can be plotted by means of regression analysis. For each cabinet a 'standard energy consumption' ($E_{standard}$) can be calculated, being the energy consumption indicated on the regression line at the functionality of the particular cabinet. The Energy efficiency Index (I) is calculated as the actual energy consumption devided by the standard energy consumption:

$$I = E / E_{standard} \ (\%)$$

The value of the energy efficiency index determines the energy efficiency class of the cabinet, on the basis of the table given below.

Table *Energy efficiency classes*

Energy efficiency index I	Energy efficiency class
I < 55	A
55 ≤ I < 75	B
75 ≤ I < 90	C
90 ≤ I < 100	D
100 ≤ I < 110	E
110 ≤ I < 125	F
125 ≤ I	G

The following standard energy consumptions are defined:

Remote cabinets, chilled products:
- cat. 11 & 13 (open top or island site) E = 4.8 + 5.6 * F
- cat. 12 (service counter) E = 11.0 + 2.0 * F
- cat. 14, 15 & 17 (multi deck, graduated or roll-in) E = 5.4 + 13.0 * F

Remote cabinets, frozen products:
- cat. 21 & 23 (open top or island site) E = 8.1 + 7.5 * F
- cat. 26 (glass door) E = 5.5 + 7.5 * F

Integral cabinets, chilled products:
- cat. 12 (service counter) E = 2.7 + 5.7 * F
- cat. 14, 15 & 17 (multi deck, graduated or roll-in) E = 1.5 + 19.7 * F
- cat. 16 (glass door) E = 1.5 + 2.8 * F

Integral cabinets, frozen products:
- cat. 21_{cover} (glass top chest freezer) E = 2.9 + 2.0 * F
- cat. 21 & 23 (open top or island site) E = 7.6 + 10.1 * F
- cat. 26 (glass door) E = 3.8 + 14.5 * F

The categories for which no standard energy consumption has been given yet, cover about 10% of the market (estimate).

The work presented in this report (excluding the actual standard energy consumptions) has been discussed with Industry, and reflects most of the comments received.

Energy labelling of supermarket refrigerated cabinets
Final report

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Foreword

This document is the final report related to the Energy labelling of supermarket refrigerated cabinets.

A first interim report titled 'Energy labelling of supermarket refrigerated cabinets' appeared in August 1994 (TNO-ME, reference number 94-310). The contents of the first interim report have been thoroughly discussed with representatives from trade and industry in The Netherlands, Denmark and The United Kingdom.

A second interim report appeared in May 1995. In this second interim report the contents of the first report were included, where necessary revised on the basis of discussions with manufacturers and other parties. The second interim report also included new chapters on functionality and classification.

This final report is a revision of the second interim report on the basis of discussions held with manufacturers, importers and other interested parties. The fundamentals of the proposed energy labelling scheme for refrigerated cabinets are laid down in chapters 3 to 7, which also appeared in the second interim report.
The chapters 8 to 10 which have been added in this final report do not in any way affect the fundamentals of the labelling scheme, and are therefore not subject to discussion.

1 Introduction

In recent years, the conviction has grown that energy consumption must be reduced in order to attain a sustainable development. In September 1986, the council of ministers of the European Communities adopted an objective to improve end-use energy efficiency by 20% before 1995. In 1991 the SAVE programme was initiated, with the objective of increasing general energy efficiency in the medium to long term.

About 60% of the electricity consumption in modern supermarkets is used by display cabinets for frozen and refrigerated foodstuffs. For short term energy saving a number of energy saving options are available on existing cabinets, like night covers and strip curtains. For long term energy saving, it is desirable that when a new cabinet is installed, it has a good energy efficiency.

At this point it is necessary to emphasise that the question is restrained to the efficiency of the cabinet only, which means that for cabinets connected to a central refrigeration system the efficiency of the cabinet alone is under investigation, and not the efficiency of the refrigeration plant. The cabinet efficiency is the efficiency that arises when the cabinet is connected to a 'standard' refrigeration plant.
All participants in the work as described in this report, manufacturers, importers and researchers, wish to stress the equal importance of energy saving measures on the side of the refrigeration system. It is advisable to turn attention to this subject, once the current work has been completed. The labelling of cabinets, once in place, might be used as an instrument for determining refrigeration system efficiency in practice.

The Standard Product Information (SPI) of refrigerated cabinets is not a sufficient base for comparing the energy use of different cabinets, and it does not give an indication of the energy use of a specific cabinet in relation to the market average. Therefore, an energy conscious choice for a new cabinet cannot be made at the moment, even when the client would like to do so.

A study on fresh meat display cases [1] shows that it is possible to select existing display cases, that use 20% less energy than the current average consumption (figure 1).

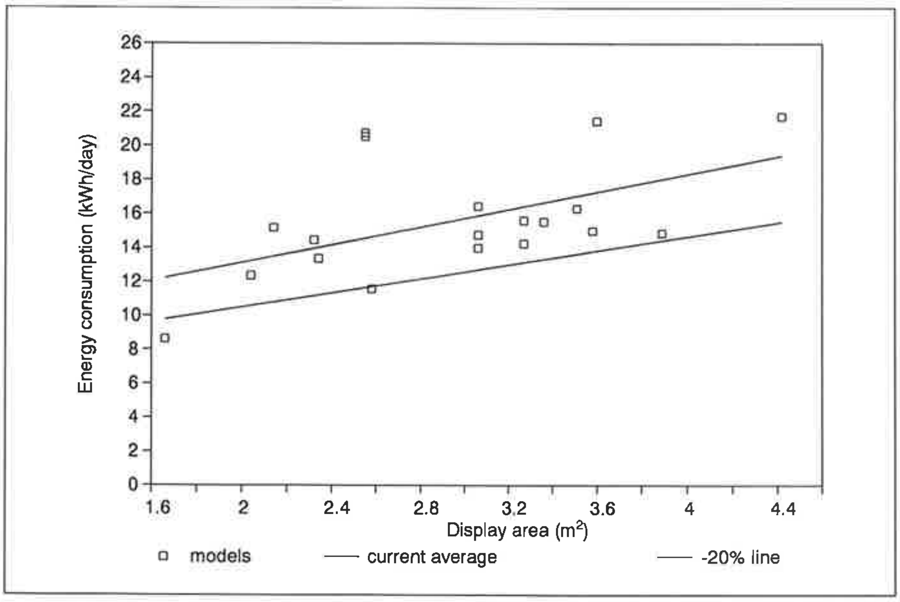

Figure 1 Energy consumption of a number of fresh meat display cases

An energy label, indicating the efficiency of a refrigerated cabinet in relation to the market average, would provide a basis for the selection of energy efficient models when acquiring a new refrigerated cabinet. Furthermore, the manufacturers will be more likely to invest in energy efficiency when the efficiency is clearly marked on the label, and thus can be used as a sales argument.

The objective of the work described in this report, is to devise a framework for energy labelling of supermarket refrigerated cabinets. This framework must be suitable as a basis for an EC directive on energy labelling of refrigerated cabinets, comparable to the recent directive on energy labelling of domestic refrigerators and freezers (94/2/EC).

In order to reach this objective, the following route is followed:
1. Description and evaluation of former attempts at labelling supermarket refrigerated cabinets. The evaluation has to point out the reasons why these attempts have remained unsuccessful.
2. Categorisation of refrigerated cabinets in a number of categories, each representing a group of appliances with the same functional and technical characteristics.
3. Definition of a single representative model. Supermarket refrigerated cabinets are often 'tailor-made', with varying lengths and options. A proposition has to be made defining which appliances can be treated as belonging to one basic model (with the same energy efficiency).
4. Inventarisation of different energy consumption measurement techniques. A measurement method, that can be acceptable both technical and procedural to all parties, will be proposed.
5. First meeting with participating manufacturers, to decide on the issues mentioned in 1 - 4 (covered in the first interim report [2]).

6. Defining the functionality of models in each category of supermarket refrigerated cabinets. The functionality of a refrigerated cabinet is 'the service rendered', in the filed of domestic refrigeration for instance the functionality is given by the adjusted volume.
7. Drawing up a method for classification in terms of energy-efficiency. It is probable that a method will be proposed, that follows the lines of the labelling scheme for household refrigerating appliances (energy efficiency levels A-G).
8. Second meeting with participating and non-participating manufacturers, to decide on the issues of functionality and classification (covered in second interim report [3]).
9. Update of the work performed on the basis of comments from manufacturers and other concerned parties.
10. Application of the labelling methodology, using the available results of energy consumption measurements. Defining reference energy consumption lines (mediate energy consumption level in the labelling scheme) on the basis of available measurement results.
11. Final report to the E.C. and parties concerned.

This final report covers tasks 1 to 10 of the route described above.

Literature referred to in the introduction

[1] Analysis of the application of WET (Energy Saving in Appliances Act) to chiller and freezer units. Cabinets for unpacked meat products
S.M. van der Sluis
TNO-ME, ref.no. 94-080 (March 1994).

[2] Energy labelling of supermarket refrigerated cabinets
Interim report
F. Elefsen, A. Gigiel, D. Maimann and S.M. van der Sluis
TNO-ME, ref.no. 94-310 (August 1994).

[3] Energy labelling of supermarket refrigerated cabinets Second Interim report.
F. Elefsen, A. Gigiel, D. Maimann and S.M. van der Sluis
TNO-ME, ref.no. R95-164 (May 1995).

2 Former attempts at labelling of refrigerated cabinets

2.1 The 'Commercial refrigeration energy indicator'

At the request of the Dutch central industrial board for the retail trade (HBD), TNO has carried out research on the possible introduction in The Netherlands of a 'commercial refrigeration energy indicator' (which is for all purposes equivalent to an energy label).
The research works were carried out in the period 1984 - 1987, starting with the setup of a labelling framework, and ending with a pilot study. Due to differences of opinion amongst the parties involved in the pilot project, the 'energy indicator' was never introduced in practice.

Of the research work concerning the labelling framework, two interim reports (in Dutch) and a final report have appeared.
The first interim report describes an inventarisation of international teststandards, a study on the demands for food storage and a study of the Dutch juridical aspects concerning the introduction of an energy label in The Netherlands. The second interim report describes three important issues:
- design of the energy label;
- measurement of power consumption of several refrigerated cabinets in practice;
- testprocedure to determine energy consumption at different test conditions.

The final report [1] gives a brief summary of the interim reports, and furthermore deals with the energy indicator test conditions.

Of the work concerning the pilot project on the commercial refrigeration energy indicator, a number of publications have appeared in Dutch literature [2, 3, 4]. The pilot consisted of the application of the framework to 12 frozen food cabinets, in cooperation with the manufacturers/importers of the cabinets. Some recommendations concerning the test method are given. However, the test results on the cabinets revealed that only one out of the 12 cabinets tested performed satisfactory - all other cabinets showing too high storage temperatures.

2.2 Evaluation of the 'Energy indicator' project

In spite of the efforts, the Commercial Refrigeration Energy indicator developed by TNO was not introduced in the market. To ascertain the reasons or causes why the Energy Guide was not introduced, a number of parties involved have been interviewed at the start of the EC Energy labelling project. In this way we hope to avoid the problems, that caused the failure of the commercial refrigeration energy indicator, and to find constructive solutions instead.

According to representatives from the retail trade, the main reasons that the introduction of the Energy indicator did not take place are:
- the costs of the Energy indicator would affect the selling price in a negative way;

- the fact that after testing of the frozen food display cases only one of the twelve met the requirements with respect to product temperatures; the dealers are mostly importers and they did not have enough influence (at that time) on their foreign manufacturers to press for higher quality with respect to cabinet temperatures.

The project manager at TNO and several researchers give the following reasons as to why the Energy indicator was not introduced:
- pressure from the retail trade was not big enough to push the dealers to take concrete action to develop the Energy indicator;
- there was not enough interest from the side of the dealers in developing the Energy indicator;
- the fact that out of the twelve frozen food display cases only one met the requirements;
- in The Netherlands there are almost only importers and no manufacturers. The Dutch importers have relatively little influence on the (European) manufacturers, as the Dutch market is relatively small;
- because of the many parties involved in the project, it was extremely difficult to reach consensus, which hampered the decision making.

Dutch manufacturers, importers and installers who were involved in the project, give their own reasons why the Energy indicator remained unsuccessful:
- Dutch manufacturers produce only a small percentage of the cabinets that can be found on the Dutch market;
- Dutch importers have only little influence on their foreign manufacturers;
- the extra costs involved in the Energy indicator have a negative influence on the competitiveness of the models with Energy indicator - especially since the Dutch market is a ‘price market’;
- the refrigerated cabinet is only a small part of a refrigeration installation; the overall efficiency is highly influenced by the installation;
- refrigerated cabinets are often relatively unique (‘tailor made’), resulting in high costs of labelling per model;
- in the opinion of the manufacturers and importers, too much emphasis was laid on the aspect of temperature requirements; especially since no Energy indicator would be given for cabinets that did not meet -Dutch- temperature requirements.

From these interviews, a number of conclusions can be extracted that will be useful to keep in mind during the current EC energy labelling project:
- The labelling project should be Europe-wide, involving the (large) European manufacturers.
- An energy label should not be dependent on compliance with (national) temperature requirements.
- The costs for an energy label should be kept low, especially for cabinets that are produced in small quantities.
- In time, labelling or some other form of certification, must be extended to the (remote) refrigeration system to which the cabinets are connected.

2.3 Other attempts outside TNO

A literature search was made inside the ‘FRIDOC’ database of the International Institute of refrigeration (IIF/IIR). Although FRIDOC contains the abstracts of the most important journals with respect to refrigeration, no references were found concerning Energy labelling.

Concerning the USA/Canada, Japan and Australia/New Zealand, inquiries were made in the initial phase of the current work on energy labelling of cabinets but no references toward national labelling schemes for refrigerated cabinets were found.

In the line of work on the current project, two other closely related activities were encountered:

- In Austria, a comprehensive study was performed on refrigerated retail display cases, including an analysis of system energy consumption and a market overview of cabinet energy consumptions [5].
- In Canada, a system was set up entitled 'Energy performance standard for commercial refrigerated display cabinets and merchandisers'. So far, the system only describes a method for presenting the energy consumption of a cabinet per unit length, defined as the specific energy consumption (SEC). Graphs of known SEC's for different cabinet categories are presented, as well as 'standard rating' [6].

Literature referred to in chapter 2

[1] Final report commercial refrigeration energy indicator
Kok, H.J.G. and Laar, G. van
TNO-ME ref.no. 85-061 (January 1985).

[2] Pilot project commercial refrigeration energy indicator (in Dutch)
Kok, H.J.G. and Laar, G. van
TNO-ME report 8725-15443.

[3] Commercial refrigeration energy indicator (in Dutch)
Kok, H.J.G.
Koeltechniek 77 (1984) nr. 12 (December), page 303 - 305.

[4] Energy use of commercial refrigeration cabinets (in Dutch)
Vermeulen, P.E.J.
Koude & Klimaat 82 (1989) nr. 9 (September).

[5] Refrigerating Equipment in Food stores (in German)
T. Ebner, J. Geyer, A. Hartmair, H. Lawetsch, E. Naftz and K. Weingärtler
Enertec, Graz-Austria, November 1994.

[6] Energy performance standard for commercial refrigerated display cabinets and merchandisers C 657-95
Canadian Standards Association (July 1995).

3 Categorisation of cabinets

3.1 Aim of the categorisation

There are many different types of retail display cabinets. The energy consumption can be dependent on the type of cabinet and it is therefore unreasonable to compare the energy consumption of cabinets which are intended for different uses. The aim of categorisation is to group cabinets into a number of categories, in such a manner that the energy consumption of cabinets within each category can be compared with each other (when adjusted for any differences in functionality, such as volume and temperature).

Vice versa, it is not meaningful to compare the energy consumption of cabinets from different categories

3.2 Choice of categorisation

In the field of refrigerated cabinets many categorisation schemes can be found (e.g. in [1]), usually based upon the type of use for which the cabinet is intended. Although these schemes differ in detail, they are set up in a similar way.
For the purpose of labelling it is important that the categorisation is based on the type of use of the cabinets; so that cabinets in one category provide the same service to the user.
Furthermore the categorisation to be used should cover all possible types of retail display cabinets. Due to the variety of cabinet types and the appearance of new types on the market, a category of 'others' will remain necessary, but the contents of this category, and especially the market share it represents, should be kept minimal.

A categorisation scheme operated by CECOMAF (European Committee of Manufacturers of Refrigerated Equipment) [2] was examined and thought to be a suitable starting point for classifying cabinets. This scheme is used by cabinet manufacturers in Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Italy, The Netherlands, Portugal, Spain, Sweden and Switzerland and therefore has common acceptance among cabinet manufacturers. When tested against a sample of 150 cabinets some cabinets did not fit the CECOMAF categorisation, upon which five categories have been added – in a logical way – for the purpose of labelling.

The categorisation used for labelling of refrigerated display cabinets, based upon the CECOMAF categorisation, is given in table 1.
It consists of 8 categories of cabinets intended (by the manufacturer) for chilled products, and 8 corresponding categories of cabinets intended for frozen products. Furthermore there is one category of cabinets for both chilled and frozen products (combination).
Each of these 17 categories is divided in two sub-categories: one for cabinets operating with remote refrigerating systems, and one for cabinets with integral refrigerating systems.

Table 1 Categorisation for labelling of refrigerated display cabinets (for illustrations refer to appandix 1)

Cat 00 (CECOMAF 65-00) Chilled and frozen food display cabinet (combination).	
- CHILLED -	**- FROZEN -**
Cat 10 (CECOMAF 65-10) Refrigerated display cabinet (used for miscellaneous cabinets not fitting any other category)	Cat 20 (CECOMAF 65-20) Frozen food sales cabinet (used for miscellaneous cabinets not fitting any other category)
Cat 11 (CECOMAF 65-11) Refrigerated open top display cabinet	Cat 21 (CECOMAF 65-21) Chest type frozen food sales cabinet
Cat 12 (CECOMAF 65-12) Refrigerated service counter	Cat 22 (CECOMAF 65-22) Frozen food counter
Cat 13 (CECOMAF 65-13) Refrigerated island site cabinet	Cat 23 (CECOMAF 65-23) Frozen food island site cabinet
Cat 14 (CECOMAF 65-14) Multi-deck refrigerated display cabinet	Cat 24 Multi-deck frozen food display cabinet
Cat 15 Graduated refrigerated cabinet	Cat 25 Graduated frozen food cabinet
Cat 16 (CECOMAF 65-16) Display refrigerator	Cat 26 (CECOMAF 65-26) Frozen food display refrigerator
Cat 17 Roll-in refrigerated cabinet	Cat 27 Roll-in frozen food cabinet

The division of each category in 'remote' (denoted by the letter R after the category number, e.g. cat 23 R) and 'integral' (denoted by the letter I, e.g. cat 12 I) is necessary because these cabinets are not generally interchangeable to the user.

3.3 Definitions

A detailed description of each cabinet, supplementary to the description in table 1, is given in table 2. These descriptions are for the most part identical to the CECOMAF terminology. French, German, Italian, Spanish and Swedish translations can be found in the CECOMAF terminology [2].

Table 2 Detailed category descriptions

Category	Detailed description
00	Refrigerated cabinet for the sale and display of chilled or deep-frozen products. Combination cabinet for simultaneous chilling & freezing.
10 & 20	Refrigerated cabinet for the sale of products, that does not fit into any of the other categories.
11 & 21	Refrigerated display cabinet, open top, with products stored generally on one horizontal shelve. Chest type, no access to products all round the cabinet. For integral cabinets of category 21, a division is made into two categories: 'cat. 21 open' for open top cabinets and 'cat. 21 cover' for cabinets with transparent covers or lids (e.g. ice cream cabinets).
12 & 22	Glass fronted refrigerated sales cabinet with access to products from sales side only.
13 & 23	Refrigerated open top display cabinet with access to products all round.
14 & 24	Refrigerated display cabinet incorporating a number of tiered shelves for the storage of food products, with (open) front access.
15 & 25	Refrigerated display cabinet with graduated shelve, with (open) front access.
16 & 26	Upright refrigerated display cabinet with a minimum of one glass wall (glass door cabinet).
17 & 27	Refrigerated cabinet with access for products to be wheeled in (front- or backside).

The proposed labelling scheme is intended for refrigerated *display* cabinets (supermarket cabinets for the sales of products), which means that only those cabinets are subject to it, in which the refrigerated products are visible from the outside. This means that chest type cabinets with transparent covers or lids and glass door cabinets are subject to the labelling as proposed here, but chest type cabinets with solid lids or upright cabinets with solid doors are not. The cabinets with solid doors or lids are subject to the existing labelling directive for domestic refrigerating appliances.

A refrigerated cabinet is defined as a container, insulated, closed as a cabinet or open type, moveable, for storage of chilled or frozen products or for freezing, equipped to be cooled by an integral or remote mounted refrigeration system.

Remote refrigerating system - a refrigerating system, separate from the cabinet, and not usually supplied with it.

Integral refrigerating system - refrigerating system totally enclosed in or beside the cabinet which only requires an (electrical) energy supply for operation.

In appendix 1, illustrations of typical cabinets are given for each category.

3.4 On site constructed cabinets

On site constructed cabinets are not refrigerated cabinets according to the CECOMAF definition, which defines a cabinet as being moveable. Therefore, these cabinets are excluded from the labelling scheme. The same applies to the 'Cold room with glass door front' design, in which a refrigerated storage room incorporates a number of glass doors that appear on the outside as cabinets.
On site constructed cabinets are often designed as a part of an overall interior design (e.g. in bakeries). Being constructed on site, energy consumption measurements cannot be performed under normalised conditions, which would make labelling difficult. There is also no practical use for a label, when the cabinet is already in place and no alternatives can be considered.

Literature referred to in chapter 3

[1] Overview of models and stock of cooling and freezing cabinets in The Netherlands (in Dutch)
Vermeulen, P.E.J. and Laar, G. van
TNO-ME ref.no. 91-009 (January 1991).

[2] Terminology. Chilled and frozen food display cabinets
European committee of manufacturers of refrigeration equipment
CECOMAF GT2 - 002 (October 1992).

4 Definition of a single representative model

4.1 Introduction

Refrigerated cabinets vary considerably and many are 'tailor made' for specific applications. Manufactures produce a very large range of cabinet models. Upon closer inspection many models are similar from the point of view of energy efficiency; for example when the differences between them are cosmetic (e.g. different colours) or when models differ in length only.

It is in the interest of manufacturers to keep the costs for labelling as low as possible, and thus to minimise the number of energy consumption measurements needed. Therefore we recommend that for a group of models that are similar from the point of view of energy efficiency, a single representative model is chosen for which the measurement is carried out. As will be discussed in chapter 5, the measurement method will be chosen to coincide as much as possible with measurements already performed routinely by larger manufacturers.

In this chapter, a definition is given as to which different models can be represented by a single representative model. Also defined are the changes to a model that affect it's energy efficiency, so that it would need to be tested and its energy rating reported separately from the original model.
The use of the representative model is fully optional; if a manufacturer so wishes, he is fully free to label each cabinet model individually.

Some manufacturers mainly manufacture 'custom made cabinets'. With the help of the concept of the representative model, it is the intention to keep the number of energy consumption measurements at a minimum.

4.2 Coverage of the representative model

The manufacturer is free to define one or more representative models, a 'standard' model such as usually given in catalogues, without any optionals, is best suited for this purpose. This model is to be labelled according to the labelling scheme.

Any model similar to the representative model, may be labelled without any additional measurements with the same label as that of the representative model under the condition that it does not incorporate one or more characteristics as listed in table 3 under the heading 'not to be used for'.

Operating temperature & cabinet length

The most common differences between models within categories are the operating temperature and size (length) of the cabinet. Although these factors definitely influence the energy consumption they need not influence the cabinet efficiency, as will be explained in chapter 6 (functionality).

Therefore, models that differ only in length or in temperature level, can be represented by the representative model.

This does not apply to models that cover the entire range of chilling and freezing; in this case a representative model for freezing and a representative model for chilling have to be defined separately.

Cosmetic changes to the outside of the cabinet

Already noted is that cosmetic differences on the outside of the cabinet (e.g. colour, basket and bumper rails) do not influence energy consumption, and therefore models with only these differences can be represented by the representative model.

Differences that cannot be covered by one representative model

In table 3 an overview is given of the differences between models, that cannot be covered by one representative model.

Table 3 Differences not covered by a representative model

Representative model specification	Not to be used for
Shelve angle (flat or angled)[1]	Model with higher shelve angle.
Lighting	Model with the higher lighting wattage inside the refrigerated space.
Number of shelves[2]	Model with lower number of shelves.
Single or multi layered glass panels	Model with panels containing smaller number of glass layers.
Front opening height (categories 14, 15, 16, 17, 24, 25, 26 & 27)	Model with larger front opening height.
Front glass setup, unheated, mounted on top of front panel (categories 11 & 21)	Model not fitted with front glass setup.
Glass setup, unheated, mounted on top of front-, back- and sidewalls (categories 13 & 23)	Model not fitted with glass setup
Screen or canopy	Model with smaller screen or canopy, or model without screen or canopy.

1) The shelve angle is defined here as the angle with the horizontal; 'flat' shelves thus have an angle of zero degrees.

2) The possibility of representing models with different numbers of shelves by one representative model has been investigated by means of Computational Fluid Dynamics [3] and through comparative test room measurements [4]; it has been concluded that by removing shelves generally the energy consumption increases.

If a cabinet model differs from the representative model in any aspect as listed in table 3 under the heading 'not to be used for', it may not be labelled according to the representative model. In this case, there are two possibilities for labelling the cabinet:
- by labelling the cabinet according to it's measured energy consumption;
- by labelling it according to the energy consumption of 'the extreme model', which is defined as a similar model with the following characteristics:
  - maximum shelve angle;
  - highest available lighting wattage;
  - minimum available number of shelves;
  - minimum available number of glass layers in all glass surfaces;
  - maximum available front opening height;
  - no glass setups fitted;
  - no screen or canopy fitted.

All remaining factors, not mentioned so far in this paragraph, which differentiate models of cabinets in one category, necessarily lead to the need to define distinguishable representative models. For example, when two models are identical in all aspects but have a different evaporator design or have different evaporating temperatures, two representative models should be defined, and energy consumption measurements should be performed on both models.

4.3 Night covers and strip curtains

Night covers

For models that are standard or optionally supplied with night covers, two (representative) models shall be defined: one (representative) model with night covers, and one (representative) model without night covers. For both cases, the energy consumption has to be measured (see chapter 5).

Strip curtains

For models that include strip curtains as a standard, the (representative) model is defined with strip curtains and the energy consumption should be measured accordingly in the presence of the strip curtains.

For models that are optionally supplied with strip curtains, two (representative) models shall be defined: one (representative) model with strip curtains, and one (representative) model without strip curtains. The energy consumption of the model without strip curtains has to be measured. The energy consumption of the model equipped with strip curtains may be measured, or may alternatively be calculated as 66% of the energy consumption of the model without strip curtains. The figure of 66% is based on field tests [1, 2].

Literature referred to in chapter 4

[1] Energy saving by application of a strip curtain (in Dutch)
TNO - ME, ref.no. 92-121 (March 1992).

[2] Energy saving measurements on strip curtains (in Dutch)
S.M. van der Sluis
TNO - ME, ref.no. 94-162 (May 1994).

[3] The effect of shelves on energy consumption in a multi-deck retail display case
A. Foster
University of Bristol, Food Refrigeration & Process Engineering Research Centre.

[4] Measurements on a multi-deck refrigerated cabinet with 2, 3 and 4 shelves under prEN 441 (in Dutch)
G. van Laar
TNO-ME, ref.no. R95-204 (June 1995).

5 Energy consumption measurement method

5.1 Introduction

As one of the purposes of carrying out an energy labelling of display cabinets is to reduce the total energy consumption in the long term, it is a condition that the measurements take place in a comparable, well-defined and reproducible way. The measurements carried out in connection with the contemplated energy labelling are to be worked out so that they to as high an extent as possible reflect the energy consumption of normal use in a supermarket.

We propose that the energy consumption measurements be carried out by the manufacturer, according to the European standard EN 441, including the sections 5 and 12 which are at the moment of appearance of this report still draft versions (prEN 441-5 and prEN 441-12 of January 1995).
In this way, no additional measurement costs for energy labelling have to be made by manufacturers that already comply to EN 441.

For each model, or it's representative model (see chapter 4), one measurement has to be performed to determine the energy consumption of the model in kWh/day.

5.2 Integrated cabinets

For integrated cabinets the total energy consumption in kWh/day shall be measured according to EN 441 - 9; using test room climate class 3.

5.3 Remote cabinets - direct expansion

For remote cabinets with direct expansion, the electrical energy consumption in kWh/day of the cabinet only (that is all permanently located electrical power using components required for normal use) shall be measured according to EN 441 - 9; using test room climate class 3.

Furthermore, the measurements according to prEN 441 - 12 (concerning the measurement of the heat extraction rate ϕ_o in kW) shall be performed, using test room climate class 3.

For remote cabinets with direct expansion, two basic values are thus measured:
- the energy consumption of all electrical components excluding the cooling circuit (E_{cab} in kWh/day);
- the heat extraction rate (ϕ_o in kW).

Using a standard Carnot efficiency η_{carnot} the total energy consumption E in kWh/day is calculated as follows:

$$E = E_{cab} + 24 * \phi_o / \{\eta_{carnot} * T_o / (T_c - T_o)\}$$

The values of η_{carnot} and T_c (the condensing temperature) will be prescribed; the value of T_o (evaporating temperature) will be based on the suction pressure recorded during the heat extraction rate test (referred to as 'p_8' in prEN 441 - 12) and the thermodynamic data for the refrigerant specified. In this way, the calculated energy consumption figures for remote cabinets will reflect the energy use of the cabinets connected to a comparable ('standard') refrigeration plant.

The heat extraction rate ϕ is recorded over 75% of the operating time, thus excluding the defrost time and time just after defrost ('pull down'). In the calculation of total energy consumption a conversion factor of 24 (kW to kWh/day) is used to calculate compressor consumption, which does not appear to incorporate the defrosting time. In fact the 'idle' time during defrost is compensated with the extra effort for pull down after defrost.

In the calculation of total energy consumption, a value of 308.15 K (35 °C) is to be used for the condensing temperature T_c

The value of η_{carnot} reflects the carnot efficiency of 'standard' refrigeration machinery. An analysis of available measurement data shows an average value of 0.34, while an analysis of refrigerating systems using a model produces values between 0.11 and 0.37. The use of distinct values of η_{carnot} for cooling (higher value) and freezing (lower value) has been considered, but was rejected for reasons of simplicity with the argument that energy consumptions of cooling and freezing cabinets are not to be compared.
In the calculation of total energy consumption, a value of 0.34 is to be used for the carnot efficiency η_{carnot}.

5.4 Remote cabinets - indirect cooling

As for remote cabinets with direct expansion, the electrical energy consumption of the cabinet only is to be measured according to EN 441-9 (using test room climate class 3) for remote cabinets with indirect cooling. The heat extraction rate ϕ_o in kW shall be measured according to prEN 441-12, using climate class 3.

The total energy consumption E in kWh/day is again calculated, assuming a 'standard' refrigeration plant which is used to extract the heat from the secondary refrigerant. It is assumed that no heat leakage appears from the surroundings into the secondary system.
In this case, the evaporating temperature T_o of the 'standard' refrigeration plant is lower than the secondary refrigerant temperature at the cabinet inlet (Θ_i in prEn 441-12). The evaporating temperature, which is not measured, shall be calculated using the following formula:

$$T_o = \Theta_i - 3\ K$$

Furthermore, electrical energy is consumed by the pump(s) necessary for circulating the secondary refrigerant. This consumption is not measured and is dependent on the practical design of the secondary refrigerant circuit. For the purpose of labelling, the pumping energy E_{pump} in kWh/day is calculated using the following formula; assuming a pressure drop in the system equalling 2.5 times the pressure drop over the cabinet and a pump efficiency of 0.5:

$$E_{pump} = 0.001 * \tau * \{q_m * v_3 * 2.5 * (P_i - P_o)\} / 0.5$$

In the above formula, the values of q_m, v_3 and $(P_i - P_o)$ are defined in prEN 441, section 12.

The factor τ in the above formula represents the running time of the pump in hours per day. This value is not measured under prEN 441-12, so far the purpose of labelling the value is prescribed:

$\tau = 19$ for systems with hot brine defrost
$\tau = 18$ for all other systems

Due to a lack of sufficient (measured) data, the prescribed values for τ must be seen as preliminary choices that may need alteration.

The total energy consumption E in kWh/day is calculated as follows:

$$E = E_{cab} + E_{pump} + (24 * \phi_o + E_{pump}) / \{\eta_{carnot} * T_o / (T_c - T_o)\}$$

Values for η_{carnot} and T_c are prescribed as in § 5.3. The calculation of T_o and E_{pump} for the indirect cooling systems reflect common design [1].

For both direct and indirect systems, the calculated energy consumption refers to a 'standard' refrigeration plant. Although the actual energy consumption of a refrigeration plant is generally not equal to that of the standard plant, it can be mathematically proven that the 'ranking order' of cabinets remains the same: if cabinet A is more efficient than cabinet B when connected to the standard plant, it will also be more efficient than cabinet B when connected to any other actual refrigeration plant [2].

Literature referred to in chapter 5

[1] Alternative routes to indirect refrigeration systems, analysis, evaluations and new ideas
B. van der Hoogen and R. Jans
Proceedings of the 19th International Congress of Refrigeration,
Part II, page 713 - 719
The Hague, The Netherlands, August 20-25, 1995.

[2] Energy consumption measurement method.
Bristol University, FR&PERC.
Internal report (1995).

6 Functionality

Comparing the energy consumption of two cabinets is only meaningful, when they fall into the same category, and furthermore provide (nearly) the same 'service to the user'. Therefore a parameter called 'Functionality' (F) is introduced, that makes a comparison of cabinets with slightly differing characteristics possible. This parameter relates to the 'service to the user', which in this context contains 'size' and 'temperature'.

It will be clear that the functionality should be proportional to the (useful) size of a cabinet, in the light of the service rendered to the user. To quantify size, use is made of parameters that are defined in EN 441 - part 1:
- refrigerated shelf area;
- display opening area.

Considering the use of refrigerated display cabinets, emphasis is given to display qualities instead of storage qualities. Choices - per category - are given in table 4.

Table 4 Quantification of size (S) in different categories

Categories	Quantification of 'size' (S)
00	c1 * display opening refrigerated [m^2] + c2 * display opening frozen [m^2]
10, 17, 20 & 27	Display opening [m^2]
11, 13, 14, 15, 21, 23, 24, 25	Display opening [m^2]
12 & 22	Refrigerated shelf area [m^2]
16 & 26	Display opening [m^2] (opened door)

The other important parameter to include in the functionality is the temperature at which the products displayed in the cabinet are kept. From the user's point of view, this temperature is either 'sufficient' or not; which would lead to the conclusion that the functionality would either have some positive value (depending only on size), or would be zero. This way of thinking is not pursued for two reasons:

- the temperature cutoff can vary for different users in different EC member states
- it is not the intention of the labelling system to provide a 'quality' statement, other than the energy efficiency quality.

The temperature is included in the functionality, in order to be able to compare the energy efficiency of cabinets retaining different product temperatures, or in other words to compensate for those differences. The temperature term in the functionality should express the relation between energy consumption and (product) temperature. For each category of refrigerated display cabinets, such a relation must be produced.

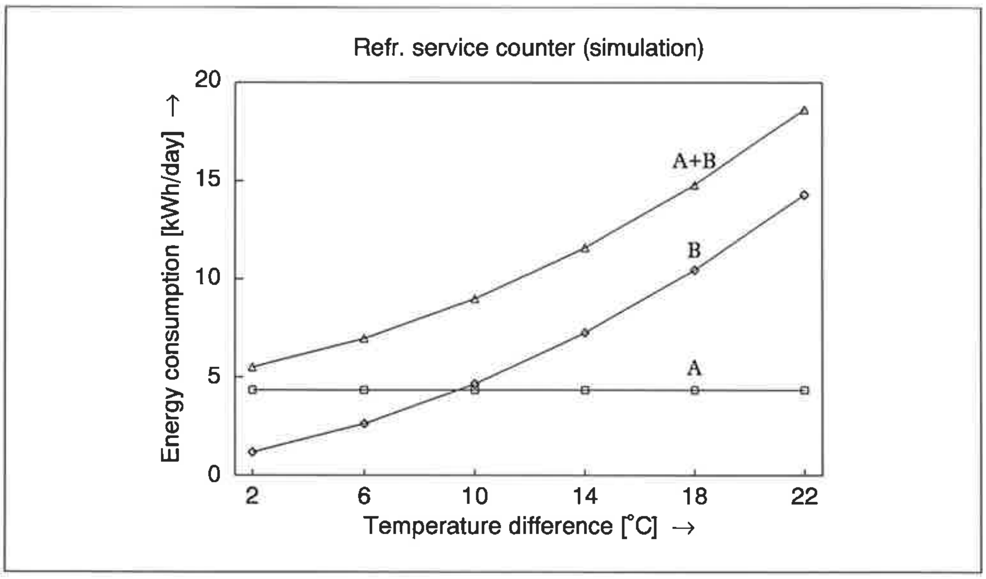

Figure 2 Simulations with a PC program [1] of energy consumption (A+B) as a function of difference between ambient temperature and (average) product temperature ΔT. A = cabinet consumption; B = compressor consumption

The total energy consumption (A+B), as shown in figure 1, consists of a constant part (A), related to the cabinet consumption (fans, lighting etc.) and of a part related to the compressor consumption, that is dependent on the temperature difference (B). For small variations in temperature difference, the compressor consumption can be described as a linear function of the temperature difference.

Therefore the functionality (F), in order to compensate energy consumption effects for small changes in temperature difference, will be defined as:

$$F = S * (c_1 + c_2 \,.\, \Delta T / \Delta T_r)$$

S = Size parameter [m^2] according to table 4.
c_1,c_2 = Constants, defined per category according to table 5.
ΔT = Temperature difference between ambient and average mean (product) temperature (as defined in prEN 441 - 5 paragraph 4.2).
ΔT_r = Reference temperature difference, defined per category according to table 5.

The value of the constants c_1 and c_2 can be deduced from the ratio of the compressor consumption ($E_{compressor}$) to the total energy consumption:

$$c_1 = E_{cab} / E$$
$$c_2 = E_{compressor} / E$$

Following the fact that the sum of compressor and cabinet consumptions equals the total energy consumption, it follows that $c_1 + c_2 = 1$. Thus for situations where the actual temperature difference ΔT equals the reference temperature difference, the functionality is equal to the size S of the cabinet.

The reference temperature difference is the temperature difference at the normal operating point of the cabinet. Values for c_1, c_2 and ΔT_r have been determined as averages per category [2], resulting in the choices listed in table 5 and table 6.

Table 5 Choices for c_1, c_2 and ΔT_r per category for REMOTE cabinets

Category	c_1	c_2	ΔT_r[°C]	Category	c_1	c_2	ΔT_r[°C]
10	0.35	0.65	21	20	0.27	0.73	43
11	0.42	0.58	21	21	0.29	0.71	43
12	0.36	0.64	21	22	0.27	0.73	43
13	0.36	0.64	21	23	0.32	0.68	43
14	0.22	0.78	21	24	0.16	0.84	43
15	0.26	0.74	21	25	0.19	0.81	43
16	0.62	0.38	21	26	0.53	0.47	43
17	0.15	0.85	21	27	0.10	0.90	43

Table 6 Choices for c_1, c_2 and ΔT_r per category for INTEGRAL cabinets

Category	c_1	c_2	ΔT_r[°C]	Category	c_1	c_2	ΔT_r[°C]
				20	0.19	0.81	43
10	0.21	0.79	21	21 (open)	0.23	0.77	43
11	0.25	0.75	21	21 (covered)	0	1.00	47
12	0.21	0.79	21	22	0.20	0.80	43
13	0.24	0.76	21	23	0.23	0.77	43
14	0.12	0.88	21	24	0.11	0.89	43
15	0.15	0.85	21	25	0.13	0.87	43
16	0.45	0.55	21	26	0.42	0.58	43
17	0.08	0.92	21	27	0.07	0.93	43

For cabinets of category 00 (combined chilled & frozen) the functionality is calculated as the sum of functionalities for the chilled part (according to it's category) and the functionality of the frozen part (according to it's functionality).

As described in [2], the values for c_1 and c_2 have been chosen per category on the basis of market average values. Furthermore, in those categories where not sufficient market data was available, estimates have been given based on intercategory tendencies (using the relations between C values in for exemple categories 11 Remote, 21 Remote, 11 Integral and 21 Integral).

A sensitivity analysis has been performed to study the effect of c_1 and c_2 values on the 'ranking' of cabinets [3]. From this analysis (using market data) it could be concluded that even for very large variations in c_1 and c_2 values, the ranking order did not change: if cabinet A is more efficient than cabinet B at a certain choise of c_1 and c_2, it will stil be more efficient at another choise of c_1 and c_2.

The concept of functionality is used to compensate for small temperature differences. These temperature differences cover the range in which the cabinets are suited for the same purpose from the user's viewpoint. When a user chooses a cabinet for a certain purpose, only cabinets with temperatures in a limited range are considered and compared.

Literature referred to in chapter 6

[1] Rekenmodel koel- en vriesmeubelen (calculation model refrigerated cabinets)
PC-program by Novem, Profile Engineering and TNO
Novem, The Netherlands (1992).

[2] Energy labelling of refrigerated display cases
F. Elefsen, A. Gigiel and S.M. van der Sluis
Proceedings of the 19th International Congress of Refrigeration
Part II, page 752 - 759
The Hague, The Netherlands, August 20-25, 1995.

[3] Analysis of ranking order at different α-values
J. Evans
Bristol University, FR&PERC internal report (1995).

7 Classification and label

Based on the defined functionality, the cabinets that are properly documented as provisioned under EN 441 including draft sections prEN 441-5 and prEN 441-12 can be labelled. When plotting the energy consumption against functionality for the cabinets, a 'cloud of points' arises, through which an average can be found by means of linear regression analysis. This has been illustrated in figure 3. The regression line represents the 'market average' of energy consumption at any given functionality in the range of interest. Regression lines are given in chapter 8.

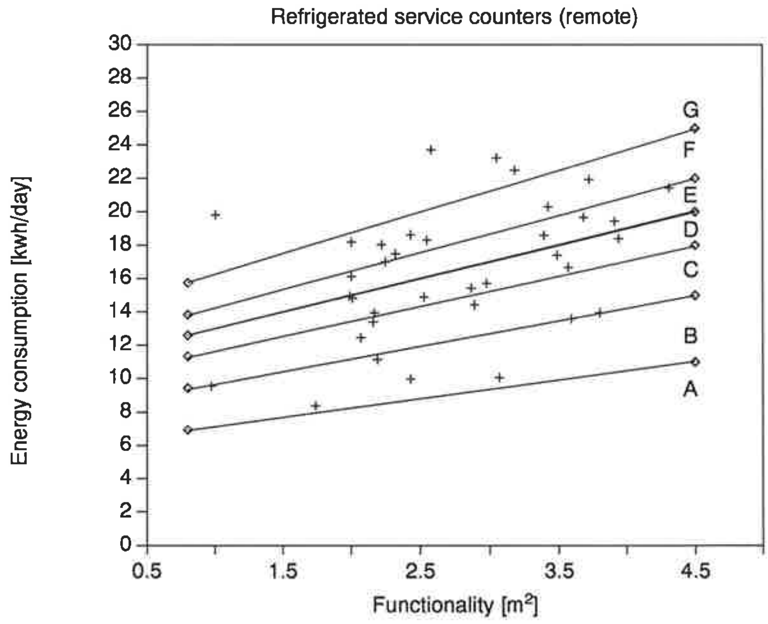

Figure 3 Energy consumption as a function of functionality in category 12, with the regression line shown thick

In figure 3 not only the regression (or average) line is shown, but also the lines representing 55, 75, 90, 110 and 125% of the average. These lines form the boundaries between different energy efficiency classes (A..G).

For each cabinet a 'standard energy consumption' ($E_{standard}$) can be calculated, being the energy consumption indicated on the regression line at the functionality of the particular cabinet. The Energy efficiency Index (I) is calculated as the actual energy consumption devided by the standard energy consumption:

$$I = E / E_{standard} \ (\%)$$

The value of the energy efficiency index determines the energy efficiency class of the cabinet, on the basis of table 7.

Table 7 Energy efficiency classes

Energy efficiency index I	Energy efficiency class
$I < 55$	A
$55 \leq I < 75$	B
$75 \leq I < 90$	C
$90 \leq I < 100$	D
$100 \leq I < 110$	E
$110 \leq I < 125$	F
$125 \leq I$	G

It can be noted that the boundaries between efficiency classes are not spaced equally, but that the classes become 'broader' as they are further away from the market average (100%). This is done in order to spread more evenly the number of models in each efficiency class, which would otherwise be concentrated in classes D and E (assuming a normal distribution of efficiencies).

The energy efficiency class is the most prominent feature that appears on the energy label. Further information that should appear on the energy label is:
- Manufacturer or Brand
- Type designation
- Category (acc. to table 1)
- Size (acc. to table 4) in m^2
- (Optional) Volume in litres
- Average mean temperature (EN 441-5) in °C
- Energy consumption of cabinet (EN 441-9) in kWh/day
- For remote cabinets/direct expansion:
  - Evaporating temperature in °C
  - Heat extraction rate in kW
- For remote cabinets/indirect cooling
  - Refrigerant entrance temperature in °C
  - Heat extraction rate in kW
  - Pump energy consumption in kWh/day as defined in chapter 5.

It should be noted on the label that all values refer to EN 441, and are measured at climate class 3.
An example of how the label could look, is given in figure 4.

Energy labelling of supermarket refrigerated cabinets
Final report

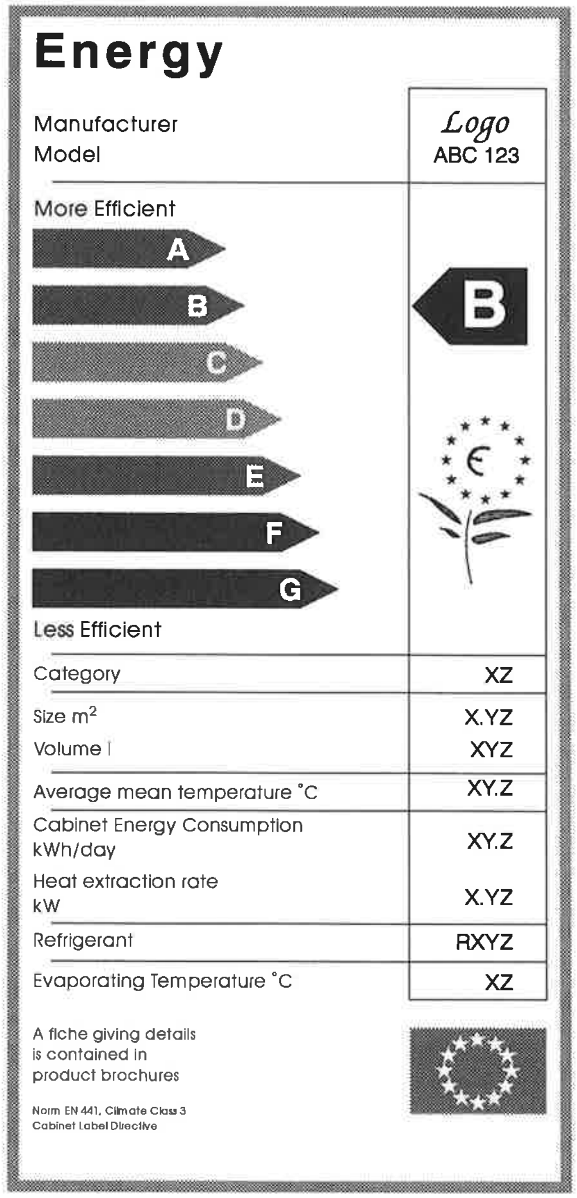

Figure 4 Possible design for refrigerated Cabinet energy label (label for a remote cabinet with direct expension)

8 Market average energy consumption lines

For the classification of a cabinet (class A..G) in terms of energy efficiency it is necessary to know the market average energy consumption for each category. The market average energy consumption is given in relation to the functionality by means of a 'line' that gives the market average consumption at each functionality.

It is often assumed in studies on display cabinets that the energy consumption is directly proportional to the size of the cabinet [1,2], thus making it possible to specify (per category) a constant ratio between energy consumption and size, expressed in kWh/m^2.

This assumption ignores the effect of sidewalls. The sidewalls have a direct effect on energy consumption because heat flows through the sidewalls, thus increasing the load on the cabinet. The sidewalls also have an indirect effect on energy consumption, because the circulation air flow pattern in the cabinet is disturbed near the sidewalls. The view that can be taken regarding the energy consumption is that it consists of a fixed amount (independent of size) representing the sidewalls, and another part that is proportional to the cabinet size. In this case the relation between energy consumption and functionality would be a straight line, with a certain positive value for energy consumption at zero functionality (equal to the fixed amount of energy that represents the sidewalls). The general formula for such a line giving energy consumption E in relation to Functionality F is:

$$E = A + B * F$$

In the above formula, the value of the constant A (kWh/day) represents the fixed amount of energy accountable to the side walls. In the simple proportional assumption [1,2], the value of the constant A is taken to be zero, and only the constant B ($kWh/m^2.day$) is specified.

In the current work on energy labelling of refrigerated display cabinets, the relationship between market average energy consumption and functionality has been based on statistical treatment of market data by means of linear regression analysis. The results of regression analyses in different categories (remote and integral) all show regression lines similar to the formula given above, with a non-zero positive value of the constant A.

The market data that was used as a basis for the regression analyses includes measurements taken over the last 15 years by TNO in routine cabinet testing under the ISO 1992 standard (the predecessor of EN 441), as well as measurements taken at Bristol University, and measurements from the Unilever Research Laboratories over 1994 concerning integral (ice cream) cabinets. Furthermore, over 250 companies from all over Europe were asked to supply energy consumption data on refrigerated cabinets.
In the collection of energy consumption data, no preference whatsoever has been given to any source of data. It is therefore thought that the obtained data is a fair representative for the current (1995) market situation in the EC

The results of the statistical analyses to determine the market average energy consumption (regression line) for the different categories are presented in table 8 (remote cabinets) and tabel 9 (integral cabinets). Regression line plots are given in Appendix 2. For some categories, not enough market data was available to calculate the regression lines.

This is generally due to the fact that sufficient data per cabinet (energy consumption, heat extraction rate, product temperature, evaporating temperature and size) is difficult to obtain, in some cases this is due to the fact that categories have been defined (in a systematic way) in which as yet no models have appeared on the market (e.g. categories 25 and 27). It is estimated that the categories for which no average energy consumption has yet been given, cover about 10% of the total market.

Table 8 Market average energy consumption per category, REMOTE cabinets
E = total energy consumption (kWh/day), F = Functionality (m^2)

Category	Market average energy consumption (kWh/day)	Category	Market average energy consumption (kWh/day)
10		20	
11	4.8 + 5.6 * F	21	8.1 + 7.5 * F
12	11.0 + 2.0 * F	22	8.1 + 7.5 * F
13	4.8 + 5.6 * F	23	
14	5.4 + 13.0 * F	24	
15	5.4 + 13.0 * F	25	
16		26	5.5 + 7.5 * F
17	5.4 + 13.0 * F	27	

Table 9 Market average energy consumption per category, INTEGRAL cabinets
E = total energy consumption (kWh/day), F = Functionality (m^2)

Category	Market average energy consumption (kWh/day)	Category	Market average energy consumption (kWh/day)
		20	
10		21 COVER	2.0 + 2.0 * F
11		21 OPEN	7.6 + 10.1 * F
12	2.7 + 5.7 * F	22	
13		23	7.6 + 10.1 * F
14	1.5 + 19.78F	24	
15	1.5 + 19.7 * F	25	
16	1.5 + 2.8 * F	26	3.8 + 14.5 * F
17	1.5 + 19.7 * F	27	

For cabinets of category 00 (combined chilled & frozen) no single regression line is given. The standard energy consumption for such a cabinet, needed to define the energy efficiency Index I, is the sum of standard energy consumption of the chilled products part and the standard energy consumption of the frozen products part.

Literature referred to in chapter 8

[1] Refrigerating Equipment in Food Stores
T. Ebner, J. Geyer, A. Hartmair, H. Lawetsch, E. Naftz and K. Weingärtler
Enertec, Graz-Austria, November 1994.

[1] Energy performance standards for commercial refrigerated display cabinets and merchandisers C 657-95
Canadian Standards Association (July 1995).

9 The energy label versus temperature requirements

When a retailer plans on acquiring a new cabinet, the most important aspects taken into consideration are (following a questionnaire conducted under technical staff of large supermarket chains in The Netherlands [1]):
- the maintenance of optimal climate (temperature & humidity) conditions in order to keep product quality as high as possible;
- the quality of display and the accessibility of products.

Energy consumption – or efficiency – is not mentioned as an important aspect, except in the case of open frozen food cabinets (such as islands and wall cabinets).
The energy label is especially intended to make it possible to select an efficient cabinet, once the range of cabinets has been narrowed down to those cabinets that fullfill the conditions set by the user on cabinet type, design and product temperature.
The intention of the energy label is to classify the cabinet on energy efficiency only. The label is not intended to classify the cabinet in terms of 'quality' or temperature requirements: in fact all cabinets, whether temperature requirements are met or not, can be labelled.

It might appear that a cabinet that does not meet the user's temperature requirements uses less energy than a cabinet that does meet the requirements, and would therefore recieve a 'better' labelling classificiation. This is not the case since the energy labelling is not based on energy consumption only, but on energy efficiency. Efficiency uses the concept of 'what service do you get for your money (energy)', which has been defined in chapter 6 as 'Functionality'. The functionality of a cabinet gives it's size, with a correction for the temperature at which the products are kept.

The following example – taken from the labelling database – can be used to illustrate the fact that a higher energy consumption, due to a lower product temperature, can still result in a better labelling class:

Cab 1	Energy consumption = 5.43 kWh/m^2.day Mean product temp. = 1.2 °C Efficiency Index I = 87.9 % Labelling class: C

Cab 2	Energy consumption = 5.34 kWh/m^2.day Mean product temp. = 4.2 °C Efficiency Index I = 94.3 % Labelling class: D

In the above example, two cabinets of the same category and roughly the same size are compared. Cabinet number 1 has a slightly higher energy consumption than cabinet 2 – due to a lower product temperature – but recieves a better classification in the labelling scheme.

Literature referred to in chapter 9

[1] Questionnaire on the development of retail refrigeration (in Dutch)
P.E.J. vermeulen and G. van Laar
TNO - MT, ref.nr. 89-040 (January 1989).

10 Dissemination

In order to facilitate the introduction of an EC labelling scheme for refrigerated cabinets, it is of paramount importance that the proposed methodology is supported by the parties who will be responsible for the actual labelling – i.e. manufacturers and importers of refrigerated cabinets. A political discussion must be entaminated in which the interests of both manufacturers/importers and the EC are taken into consideration in view of the energy labelling scheme. Beforehand a reasonable state of consensus has to be reached concerning the labelling methodology, in order to prevent the political discussions to be troubled by technical discussions.

To this purpose manufacturers, importers and other interested parties have been informed about the project, and have been asked to give their comments. The exchange of views between the project team and the parties involved has been a continuing process during the work on the energy labelling, and has been assisted by the appearance of two interim reports in August 1994 and May 1995. This has made it possible to include comments from the parties involved in the final report.

Project setup in The Netherlands

In the Netherlands, the project was set up in such a way that interested parties could participate in the work on energy labelling. In this 'collective research project' eight importers/manufacturers, four energy distributing companies and Novem (The Dutch Energy and Environment Agency) participated.

- First meeting with participants, September 7th, 1994.
  Discussion on first interim report. Energy consumption measurement method through prEN 441 and categorisation agreed – adding drawings of models for each category is suggested. It is noted that apart from labelling the cabinet, the refrigerating machinery should also be investigated. The 'representative model' remains to be discussed. The aspect of product weight loss for unpacked products cannot be taken into account (as some manufacturers would like to do), since it is not measured under prEN 441.

- Second meeting with participants, September 27th, 1995.
  Discussion on second interim report. The 'representative model' presented so far, is in fact a 'worst case' cabinet - it is agreed that the representative model will be redefined to make it possible to represent a manufacturer's 'standard' model.
  The participants are worried, that the energy label will result in 'good' energy efficiencies for cabinets that do not meet temperature requirements, whereas the cabinets that do meet temperature requirements will have poorer energy efficiencies. This aspect has been taken into account in labelling scheme, as explained in chapter 9.

Novem – and the participating electricity distributing companies – are interested in the market average energy consumptions of cabinet categories. Novem intends to use this information for the setup of a rebate scheme for investments in supermarket refrigeration efficiency; the electricity distributers are interested in a way to calculate the 'target' consumption of supermarket refrigeration plants, in order to compare this with the actual consumption.

Furthermore, the energy labelling project was presented at workshops held in The Netherlands on themes related to refrigerated cabinets:
- NVvK - Novem workshop 'Energy efficient refrigerated display cabinets'.
  November 23, 1993.
  Published in RCC Koude & Luchtbehandeling, vol. 87 nr. 5 (May '94).
- Symposium during presentation of new TNO climate chamber.
  May 10, 1995.
  Published in Koude Magazine, 1995 nr. 6 (June 1995).

Denmark

Workshop on energy labelling (1994) with participation from manufacturers, retailers and energy consultants. From this workshop a number of comments have arisen:
- The importance of using an international (agreed) categorisation is stressed.
- It is suggested to include Illustrations with the categories in the report.
- A split-up between front-loaded and back-loaded roll-in cabinets is suggested.
- The representative model is a worst case model; it would be better to have a 'standard' model as representative model.
- It is suggested to investigate the possibility of using a correction factor for identical cabinets with different cooling capacities.
- The (actual) cabinet energy consumption is dependent on the position in the shop. Note: a cabinet that is efficient in the test-room will also be efficient in a retail shop – no matter the position; the energy consumption will differ from that in the test room.
- Some comments are given on (pr)EN 441.
- There is a large difference in cabinets operating at +1 °C (with electric defrost) and cabinets operating above +5 °C (without electric defrost), even when they belong to the same category.
- Energy consumption on location is difficult to measure.
- Bakery cabinets are at a disadvantage because these can feature humidification and surplus cooling capacity (for cooling products down). These features are not recognised in EN 441 or in the Labelling scheme.
- There is a 'gray' area between domestic and retail refrigerated cabinets; which might lead to cabinets getting both domestic and retail labels. Note: in the final report, the border has been set at cabinets for *display* of goods; cabinets with transparent covers (cat 21) or transparent doors (cat 16 & 26) are seen as retail display cabinets, whereas the same cabinets with non-transparent covers, lids or doors are not.
- One supermarket chain is interested to use the labelling scheme on a voluntary basis.

Comment in writing on the second interim report was received from Vestfrost:
- Some questions concerning prEN 441 are posed, unclarity arises from the fact that different draft versions are in roulation. In the 2nd interim report the size parameter for glass door cabinets is not well enough defined.

United Kingdom

The work on the energy labelling of refrigerated display cabinets has been presented via the British Refrigeration association to UK refrigerated cabinet manufacturers (October '94).

The following comments were received upon distribution of the 1st and 2nd interim reports:
- Quest refrigeration and Manufacturing Ltd.
  Positive about energy labelling (Integral cabinets).
- Sainsbury's Retail Division.
  Energy consumption under prEN 441 (at 25 °C) is not equal to the consumption in - store (at a lower ambient temperature). Note: the cabinet 'ranking' (concerning energy efficiency) will not change.
- ASDA Stores Ltd.
  Key points influencing cabinet selection are merchandising and aesthetic features, energy consumption is a secondary consideration. Labelling must not influence the manufacturer's freedom of design.
- Energy technology Support Unit (ETSU).
  It is possible for a manufacturer to choose the (product) temperature at which the best rating is obtained. Further comments on the representative model, cabinet defrosting and classification have been taken into consideration in the final report. The question of enforcement of the scheme is important, but not within the scope of the current work.
- George Barker and Company Ltd. - Refrigerated Display.
  Notices that the energy labelling is limited to direct energy consumption during practical use, a more comprehensive (Eco) label would include TEWI.
  The onset of electronic control circuits might lead to cabinets that receive different labels depending on the temperature they are operated at; especially when fans and pumps are switched on/off at certain temperature levels.

From contacts with the UK CECOMAF representative it is clear that the mayor point of concern is the 'fairness' of the energy labelling system: is a cabinet A that has been labelled with a higher efficiency than cabinet B, also more efficient in the field under actual operating conditions? In answer to this, it was shown that the 'ranking order' of cabinets in terms of efficiency does not change with different refrigeration installations (mathematical proof), and that the ranking order does not depend on the choice made for the constants c_1 and c_2 (sensitivity analysis).

International

During the project, contacts have been established with relevant parties outside the three countries mentioned above. A short listing:
- Meeting TNO - Electrolux CR AB (Sweden), September 13, 1994.
  Electrolux notes that the labelling can only be successful when accompanied by a good enforcement scheme is ensured.
- Meeting TNO - Bonnet Névé (France), July 3, 1995.
  Questions relating to efficiency vs. temperature requirements, see chapter 9.
- Meeting TNO - Tasselli (Italy), September 4, 1995.
  Tasselli would like to include the temperature class on the label.
- Meeting with Enertec (Austria), March 16, 1995.
  Discussion on the Austrian study on retail refrigeration.

- Meeting with Epsilon Technologies (Canada), August 22, 1995.
  Discussion on the Canadian energy performance standard C657-95.
- CECOMAF (European Committee of Manufacturers of refrigeration Equipment).
  No special comments; work is not deemed necessary for the time being (July 25th, 1995). Following the presentation of the work in The Hague (at the IIR Congress), the CECOMAF has taken a more positive attitude and is more open for discussion.

A presentation of the labelling work was given at the 19th international Congress of Refrigeration in the Hague (1995) as part of a workshop on refrigerated cabinets.

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11 Authentication

Name and address of the principal
The Commission of the European Communities, directorate-general for energy
SAVE
Contract no. XVII/4.1031/93-16

Names and functions of the cooperators
F. Elefsen, Danish Technological Institute, Aarhus, Denmark
J. Evans, University of Bristol, FRPERC, Bristol, UK
A. Gigiel, University of Bristol, FRPERC, Bristol, UK
G. van Laar, TNO Institute of Environmental and Energy Technology
H. Madsbøll, Danish Technological Institute, Aarhus, Denmark
D. Maimann, Danish Energy Agency, Copenhagen, Denmark
J. Nyvad, Danish Technological Institute, Aarhus, Denmark
S.M. van der Sluis, TNO Institute of Environmental and Energy Technology
R.J.M.J. Weijers, TNO Institute of Environmental and Energy Technology

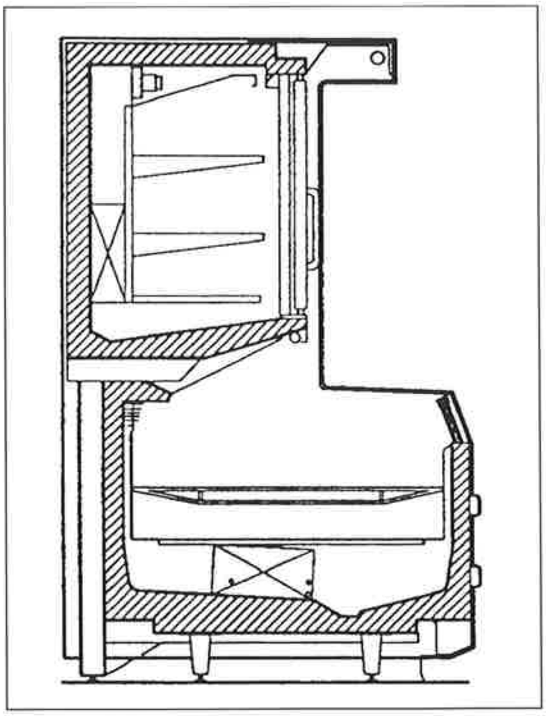
Names of establishments to which part of the research was put out to contract

Date upon which, or period in which, the research took place

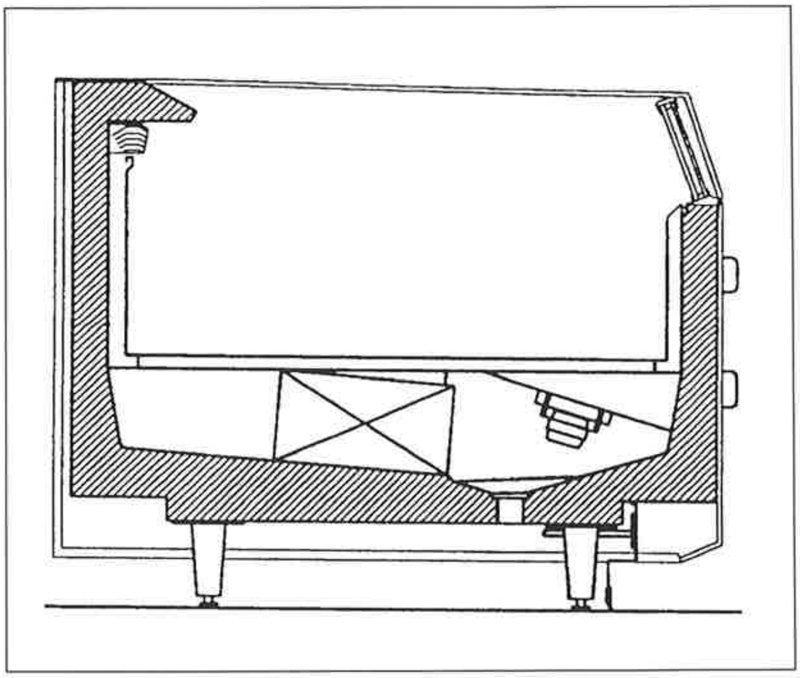
Signature	Approved by
S.M. van der Sluis research coordinator	R.J.M. van Gerwen section leader

Appendix 1 Illustrations of typical cabinets in the defined categories

On the following pages illustrations are given of typical cabinets in each of the defined categories (chapter 3).



Categories 10 & 20
Miscellaneous cabinets not fitting any other category; e.g. cabinets consisting of a combination of 2 distinctive parts



Categories 11 & 21
Open top chest type cabinets, chest type, no access to products from all sides ('wall cabinet')

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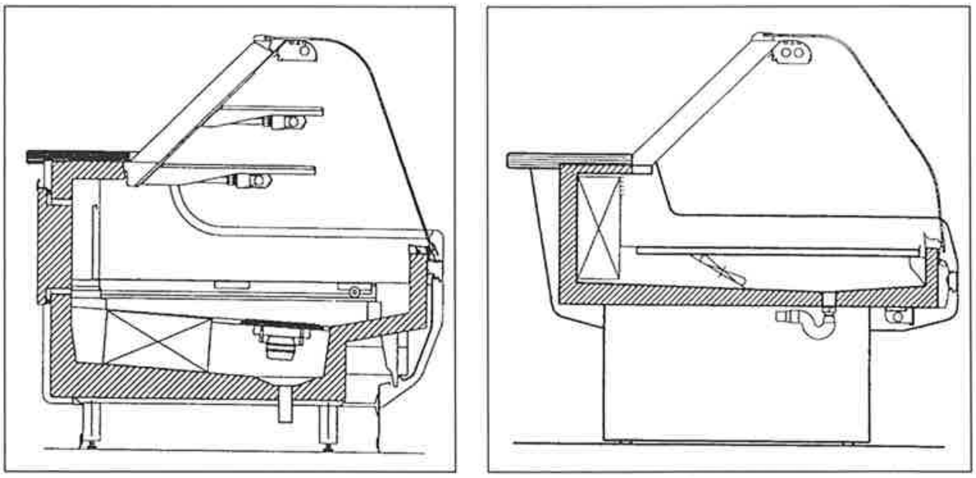
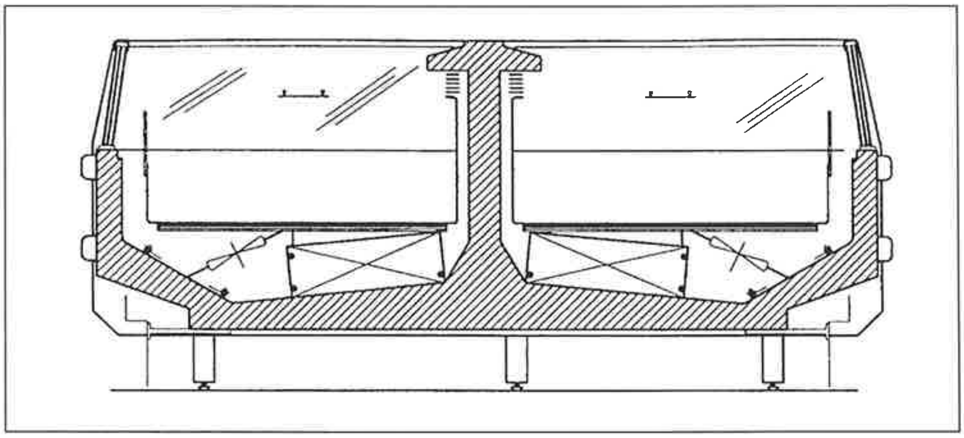
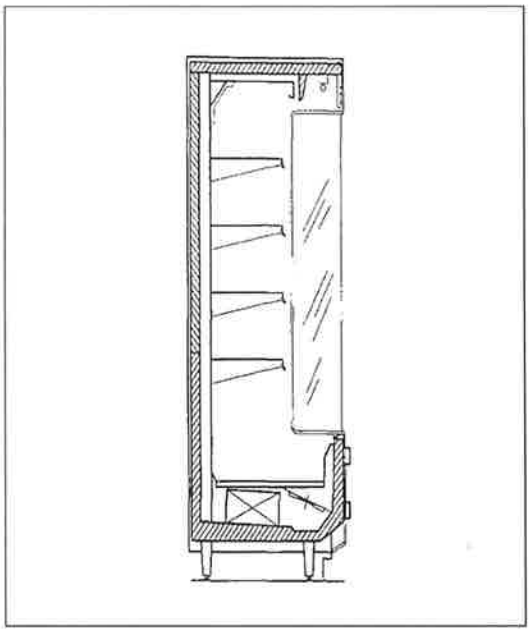


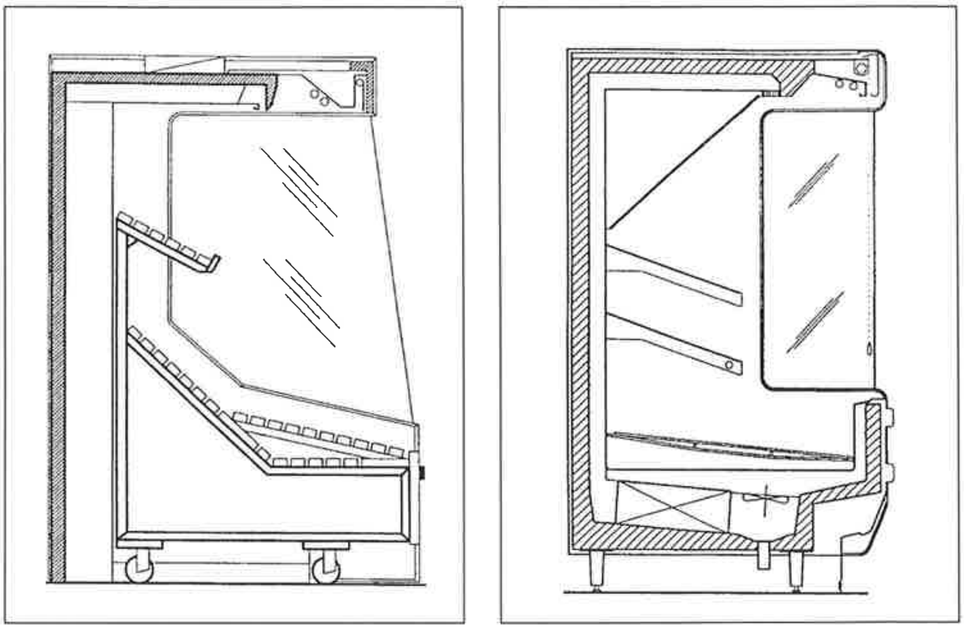
Categories 12 & 22
Service counters for refrigerated or frozen products



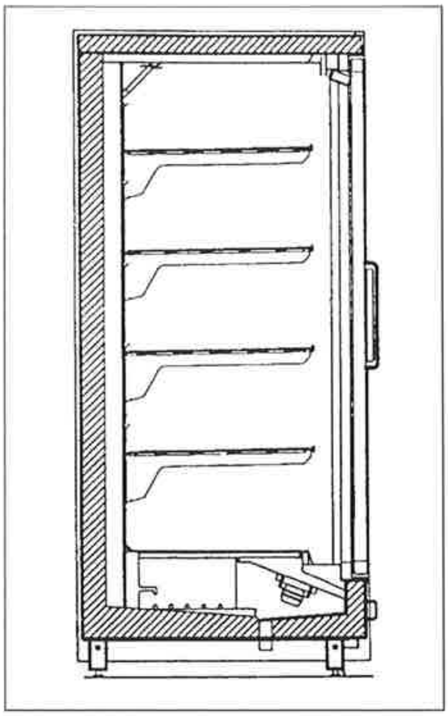
Categories 13 & 23
Open top chest type cabinets, chest type, with access to products from all sides
('island site cabinet')



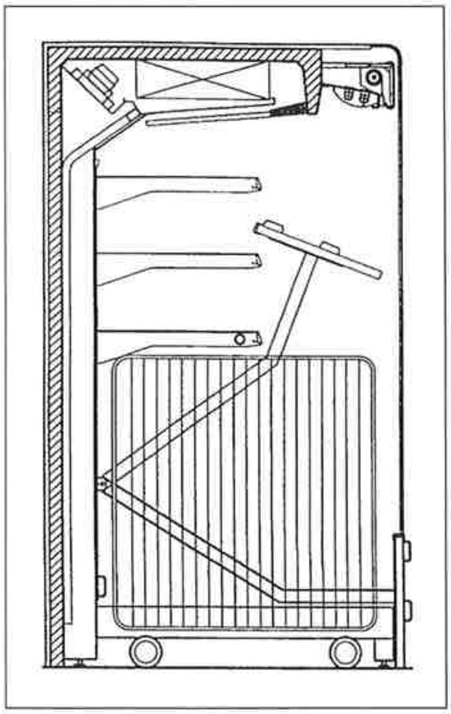
Categories 14 & 24
Multi deck display cabinet



Categories 15 & 25
Graduated cabinet, frozen or refrigerated products

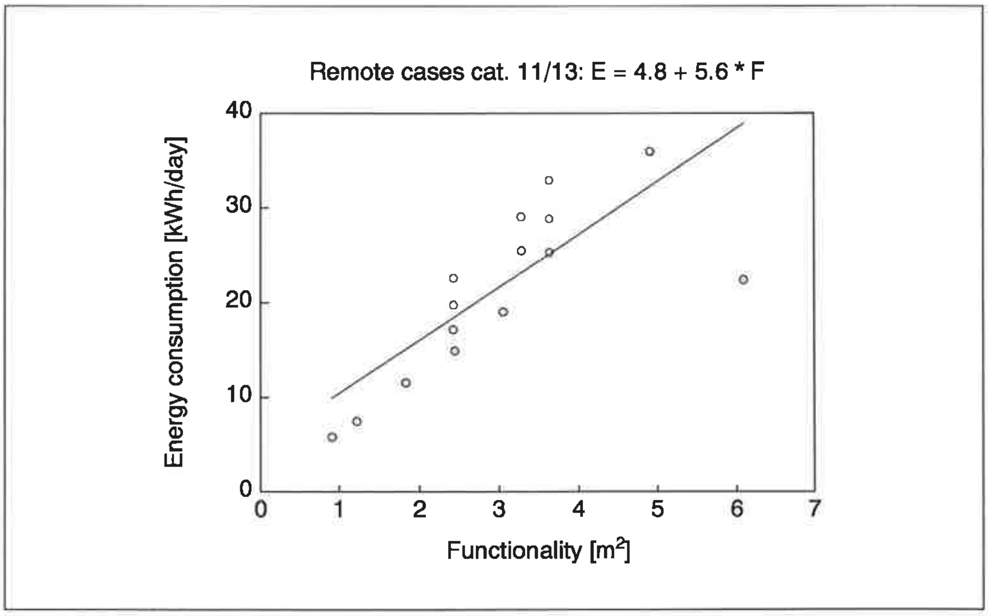


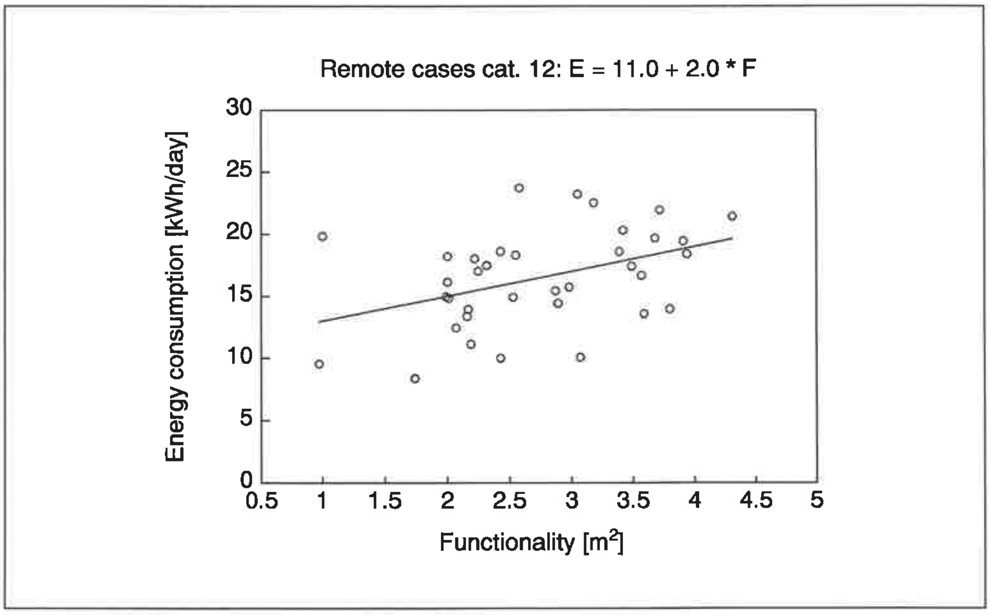
Categories 16 & 26
display refrigerator (glass door)

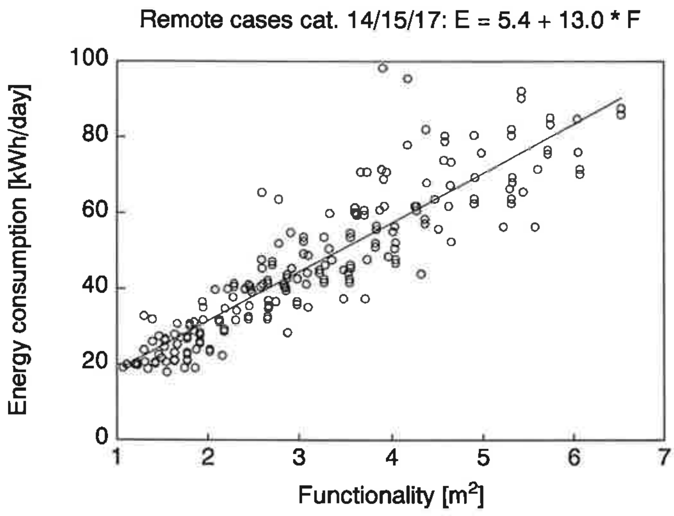


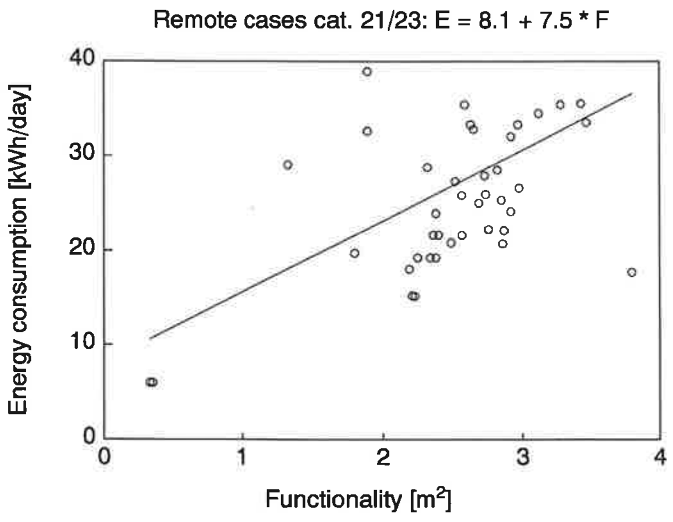
Categories 17 & 27
Roll-in cabinet (one- or two sided access; with or without shelves)

Appendix 2 Regression line plots


Remote cases cat. 11/13: E = 4.8 + 5.6 * F
Energy consumption [kWh/day]
0
10
20
30
40
0
1
2
3
4
5
6
7
Functionality [m2]


Remote cases cat. 12: E = 11.0 + 2.0 * F
Energy consumption [kWh/day]
0
5
10
15
20
25
30
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Functionality [m2]


Remote cases cat. 14/15/17: E = 5.4 + 13.0 * F
Energy consumption [kWh/day]
Functionality [m2]
0
20
40
60
80
100
1
2
3
4
5
6
7


Remote cases cat. 21/23: E = 8.1 + 7.5 * F
Energy consumption [kWh/day]
Functionality [m2]
0
10
20
30
40
0
1
2
3
4

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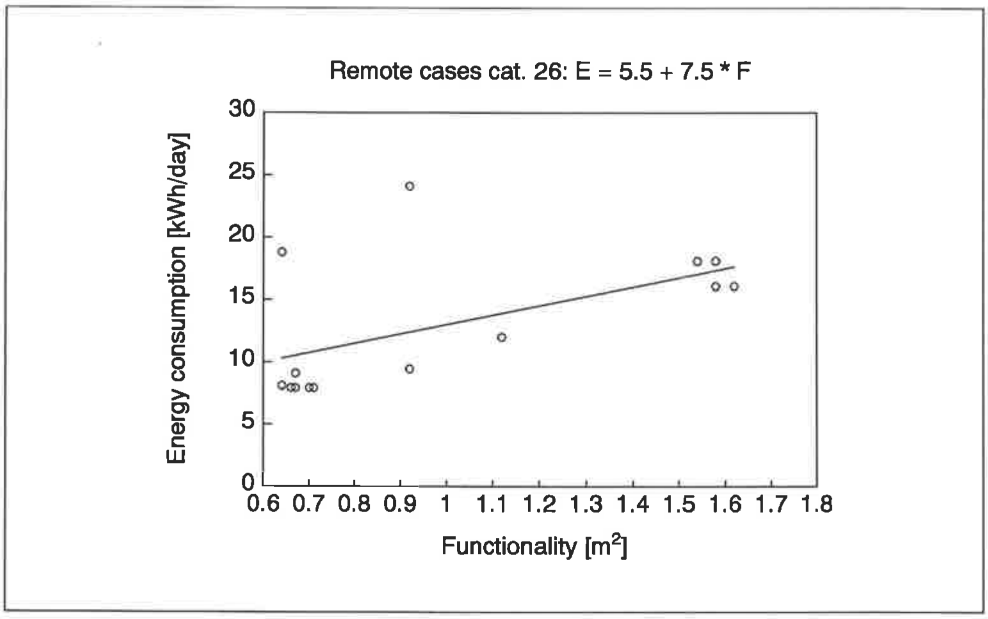
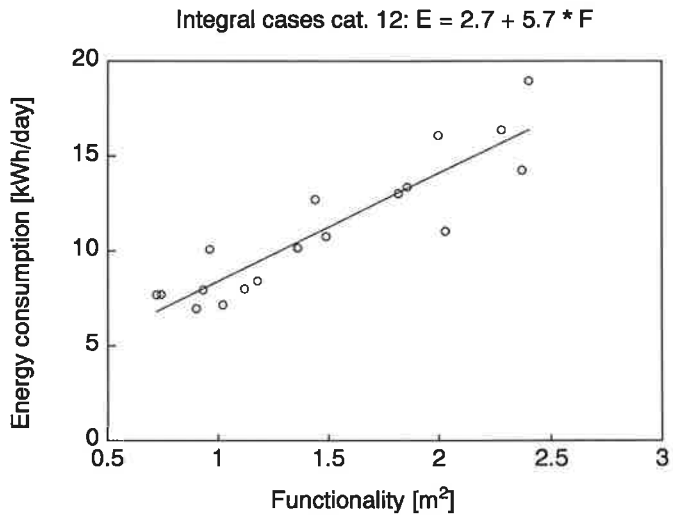
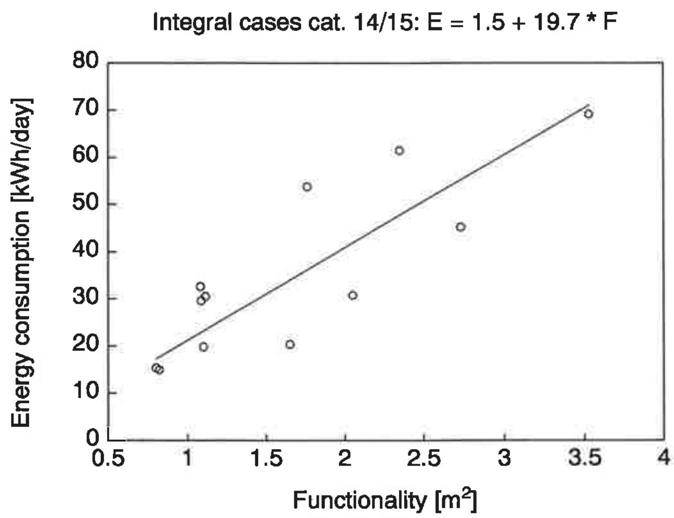



Integral cases cat. 12: E = 2.7 + 5.7 * F
Energy consumption [kWh/day]
20
15
10
5
0
0.5
1
1.5
2
2.5
3
Functionality [m²]


Integral cases cat. 14/15: E = 1.5 + 19.7 * F
Energy consumption [kWh/day]
80
70
60
50
40
30
20
10
0
0.5
1
1.5
2
2.5
3
3.5
4
Functionality [m²]

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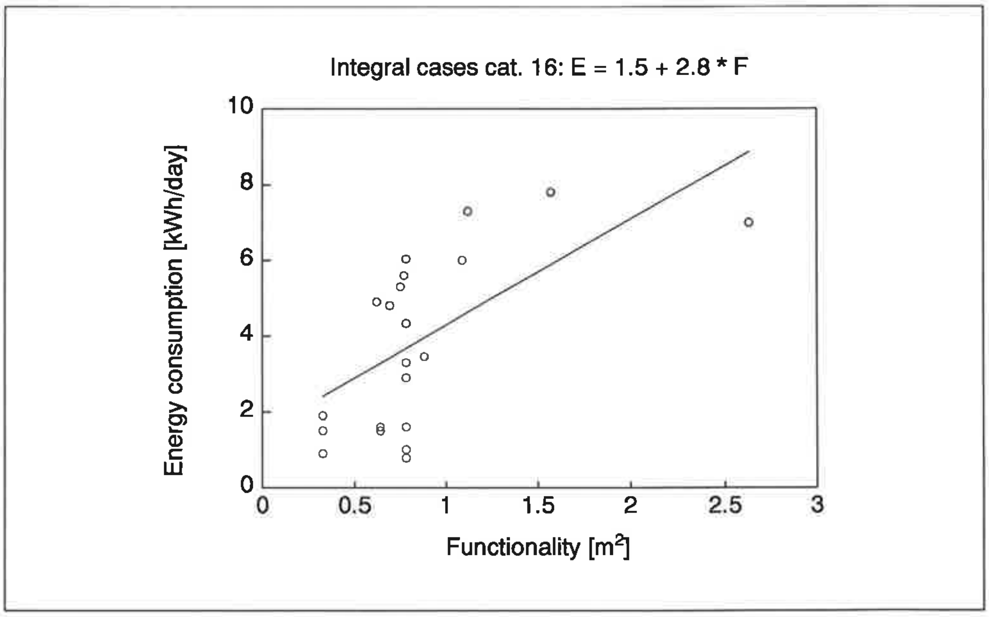

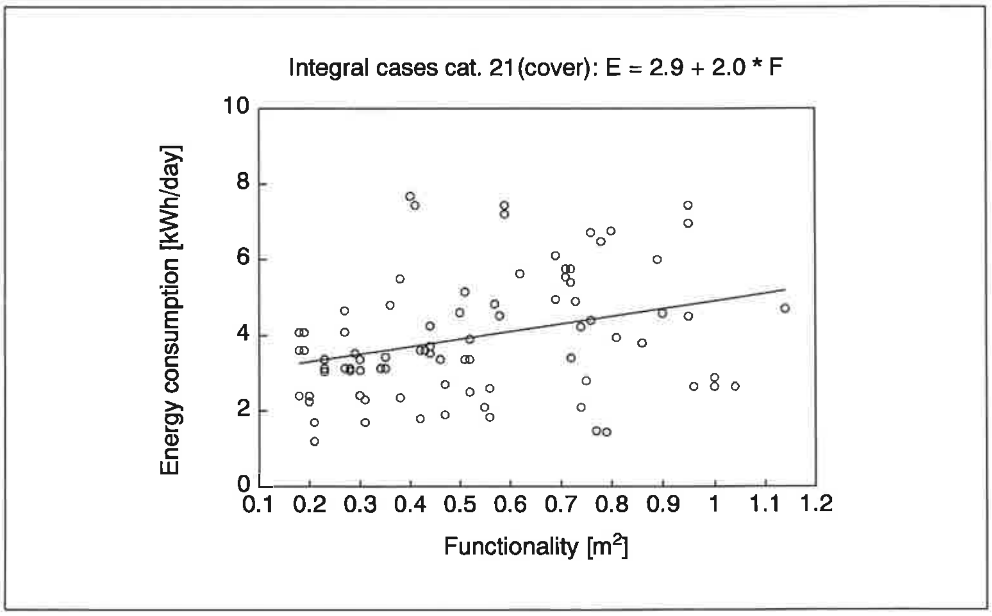

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