INTERNATIONAL ENERGY AGENCY
energy conservation in buildings and
community systems programme
Annex XII
Windows and fenestration

Step 1

The State-of-the-Art in Existing Windows and New Window Designs; a survey from eight countries

September 1986

Ann 12 1986:3

INTERNATIONAL ENERGY AGENCY

Energy Conservation in Buildings and
Community Systems Programme

Annex XII, WINDOWS AND FENESTRATION

Report from Step 1

THE STATE-OF-THE-ART IN EXISTING WINDOWS AND NEW WINDOW DESINGS; A SURVEY FROM EIGHT COUNTRIES

This report is part of the work of the IEA Energy Conservation in Buildings & Community Systems Programme

Annex XII - Windows and Fenestration

Participants in this task:

Belgium, FR-Germany, Italy, The Netherlands (Operating Agent), Norway, Switzerland, United Kingdom, United States of America.

The complete list of representatives who have contributed to this report is given in Appendix 1.

Document	: Report from work carried out under Step 1 of the project.
Distribution	: Unrestricted.
Editor	: H.A.L. van Dijk TNO Institute of Applied Physics P.O. Box 155 2600 AD DELFT The Netherlands.
Additional copies:	TNO Institute of Applied Physics.
Approximate price:	Dfl 15.--.

Delft, September 1986

CONTENTS

PREFACE

INTERNATIONAL ENERGY AGENCY

In order to strengthen co-operation in the vital area of energy policy, an Agreement of an International Energy Programme was formulated among a number of industrialized countries in November 1974. The International Energy Agency (IEA) was established as an autonomous body within the Organization for Economic Co-operation and Development (CECD) to administer that agreement. Twenty-one countries are currently members of the IEA, with the Commission of the European Communities participating under special arrangement.

As one element of the International Energy Programme, the Participants undertake co-operative activities in energy research, development and demonstration. A number of new and improved energy technologies which have the potential of making significant contributions to our energy needs were identified for collaborative efforts. The IEA Committee on Energy Resarch and Development (CRD) assisted by a small Secretariat staff, co-ordinates the energy research, development and demonstration programme.

ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS

As one element of the Energy Programme, the IEA encourages research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is encouraging various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programmes, building monitoring, comparison of calculation methods, as well as air quality and inhabitant behaviour studies.

THE EXECUTIVE COMMITTEE

Overall control of the R&D programme energy conservation in buildings and community systems is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort may be beneficial. The Executive Committee ensures all projects fit into a predetermined strategy without unnecessary overlap or duplication but with effective liaison and communication.

ANNEX XII

In June 1982 the Executive Committee approved Annex XII, 'Windows and Fenestration' as a new joint effort project, with the Netherlands acting as 'Operating Agent' to co-ordinate the work.
The following countries are participating in this project:

BELGIUM, FEDERAL REPUBLIC OF GERMANY, ITALY, THE NETHERLANDS, NORWAY, SWITZERLAND, UNITED KINGDOM, UNITED STATES.

The project consists of 5 steps:

Step 1: Survey the state-of-the-art in all types of existing windows and future designs (including glazing and combinations of glazing and insulating and/or sunshading systems).

Step 2: Survey the state of the art in thermal and solar properties of windows and compare definitions, test methods, calculation procedures and measured, calculated or assumed data, wherever possible converted to one or several sets of standardized conditions. The aim: to try and cover all existing (and sometimes conflicting) information in this field in an extensive report for 'expert groups'.
A separate report contains summarized information for general use among architects, consultants and manufacturers.

Step 3: Review and analyse existing simplified steady-state calculation methods dealing with gains and losses through window systems. These methods can provide a preliminary and global figure for the influence of the window on energy consumption without considering the interaction with the buiiing, occupants and climate in a detailed way.

Step 4: Adapt and compare existing dynamic calculation methods dealing with the influence of window type, size and orientation on energy consumption and thermal comfort in buildings.
Normally, a good window design will often be treated with a global approximation, with the consequence that specific features of the design cannot be revealed properly. With a study specifically focused on windows complex systems also can be simulated, like multi-layer systems with foils, coatings and/or gas fillings and e.g. systems at which the control of an openable window, insulation panel, or sunshading is associated with indoor temperature and/or time and/or intensity of solar radiation. A thorough consideration of the effect of windows calls for a calculation model that can handle such simulation.

Step 5: Apply unsteady state models in a series of selected, general sensitivity studies and thereby produce extensive information on optimal window design from an energy point of view for different buildings (mass, insulation), occupants' behaviour schemes (control of equipment, internal heat) and climatic zones. The results are aimed at groups like architects, manufacturers and policy makers.

1. INTRODUCTION

This report describes part of the work within Step 1.
The aim of the work was to review the state-of-the-art in existing windows and in new window designs, as a basis for the activities within Steps 2 to 5.
A clear understanding of the traditional, current and possible future window applications is a conditio sine qua non for the comparison of the various national approaches concerning definitions and approximations of basic window physics and the influence of the windows on the energy consumption.
The present situation on the window market is reflected by national or regional building regulations, standards and codes.
In a separate report building regulations, standards and codes concerning thermal and solar performance of windows are surveyed.

2. METHOD

This report is based on the results of various co-ordinated actions from the participants in the project:

1. Questionnaires on the existing state-of-the-art of windows and the state-of-the-art in new window designs have been distributed among the participants (see appendix 1). In some countries these questionnaires were distributed among e.g. architects and manufacturers, in other countries a more centralised approach was chosen.
   From Belgium, Italy, The Netherlands and Norway in total 27 replies were received.

2. Switzerland and Germany produced as part of their efforts within the project extensive documents describing the state-of-the-art in their respective countries ([1], [2], [3]).
   The Swiss document provides a.o. statistical data of window applications in practice, the German documents show a.o. a very detailed description of all kinds of window features.
   These documents also contain valuable information concerning measurement methods, U-values and building regulations in both countries. This information will be referred to in the other reports within this project. Furthermore, a paper from the UK concerning the renovation market ([4]) was used.

3. Neither the completed questionnaires, nor the more extensive documents, however, contained sufficiently homogeneous information for a survey in which comparisons could be made between the participating countries. Therefore, each participant was asked to write a summary on the state-of-the-art in windows and in addition a summary with a - maybe personal - view on future developments.

4. Finally, each participant was invited to fill in a table with a few words characterizing the national situation. This table has been included in this report as chapter 5.

3. STATE-OF-THE-ART IN EXISTING WINDOWS

3.1. Frame Materials

a. General

The prevailing material for older existing window frames is wood. In new buildings insulated aluminium and PVC frames have gained a certain share of the market. The preference for a certain frame-material however, strongly depends on the type of building.

b. Residential buildings

For new residential buildings wood (figures 1, 2 and 3) plays still a predominant role, ranging from 80-90 percent in e.g. Norway, the Netherlands, UK and Italy to 60-70 percent in Belgium, Germany ([5], [6]) and Switzerland.

The type of wood shows a strong variation: in Switzerland and Norway mainly softwood, in e.g. Belgium mainly hardwood (meranti and afzelia). In the Netherlands the share of hardwood (mainly meranti) increased drastically during the 1970s from 15 to 60 percent.

In the USA wooden windows are often sold with aluminium or vinyl cladding. In Switzerland 20% of the frames for new houses consists of a combination of wood and aluminium.

The market for plastic frames (mainly PVC, also PUR) in new dwellings is in some countries still small, ranging from less than 1 percent for e.g. the Netherlands, to 15 percent for Switzerland. Belgium counts about 25% PVC (mainly in the rented housing sector, because of much more favourable maintenance costs). In Germany more than 40 percent is PVC material (figure 4).

Aluminium frames without a thermal break are reported still to be sold widely in the southern third of the USA.

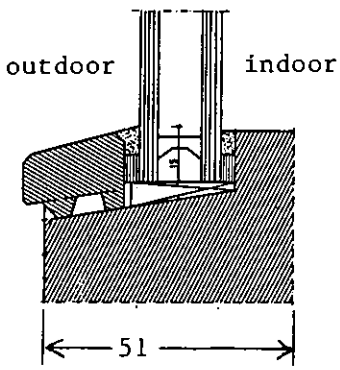


Figure 1: Example of drained wooden frame system ([7]).

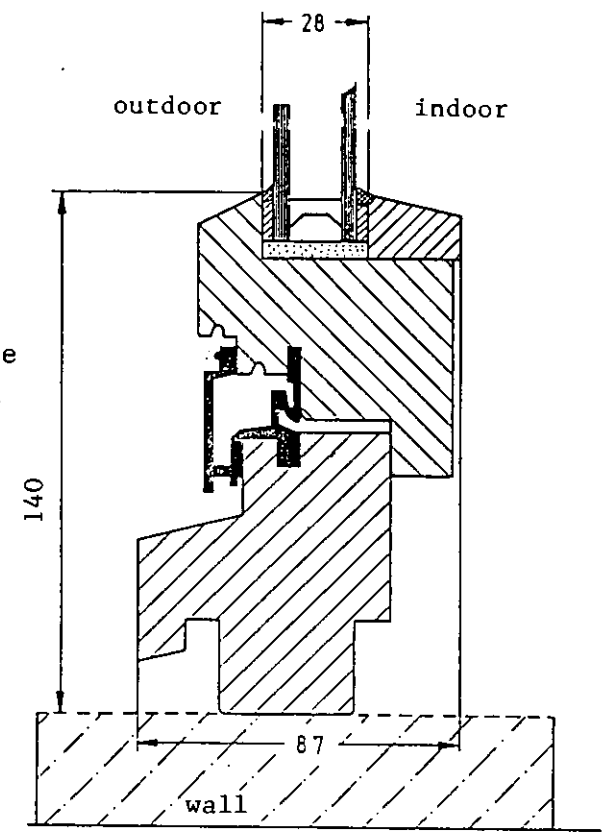


Figure 2: Example of a wooden frame with fully bedded double glazing ([5]).

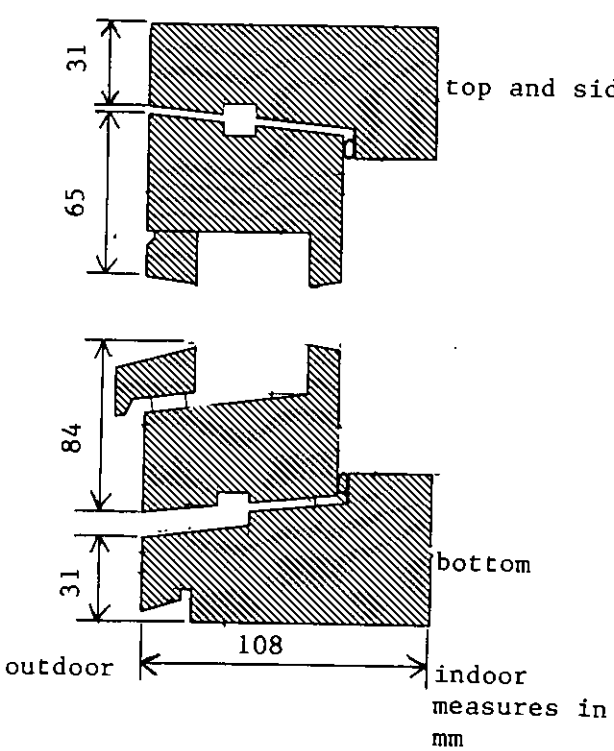


Figure 3: Example of wooden frame for sealed triple glazing ([8]).

In all countries, aluminium frames with thermal barriers gain in popularity, although the percentages of the market are still quite low: 0% for Switzerland, 5-10% for the Netherlands and Belgium, 12% in Germany (figure 5), maybe higher in the USA, particularly in southern third of the country which is experiencing the highest growth rate (e.g. Florida, Texas, southern California).
From Italy the use of steel is reported in recent low-cost housing projects.

c. Retrofit sector

Only for a few countries figures are available for the sector of replacement of windows, although in most countries this is a market sector of main importance (e.g. Germany 53% of the fenestration market). But also without hard figures it is clear that the role of alternative materials in this market sector is more significant than in the new residential building sector. In the selection process in this market sector maintenance costs play an important role. In Belgium PVC has a market share of 40 percent against about 60 percent for wood. In Germany almost 60 percent is PVC against 25 percent wood and 10 percent insulated aluminium. In the UK 90 percent is aluminium (plus where required a hardwood subframe) and about 10 percent (but growing) for PVC, with a marked exception for the public sector housing, where usually timber frames with single glazings are applied.
Another way to improve the quality of existing windows is by adding an extra sheet. For Belgium this is about 10 percent of the window retrofit-market. In the UK and the Netherlands probably the same or higher. In the USA interior and exterior "storm windows" have increased in popularity. Many of the interior systems utilize plastic film or sheet products. A wide range of possibilities exists in fixing the add-on units: wood or aluminium frames hinged or screwed on the existing window, sliding sashes (UK), plastic frames glued on the add-on sheet, or frameless (adherence tape, magnetic tapes, etc. (the Netherlands)).

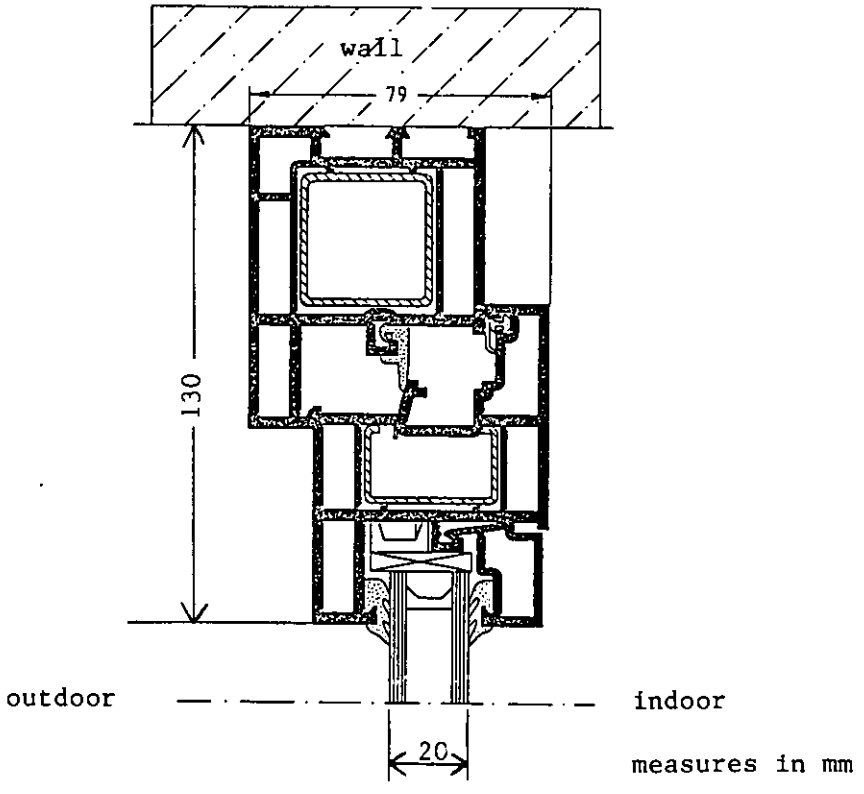


Figure 4: Example of PVC frame with steel reinforcements ([5]).

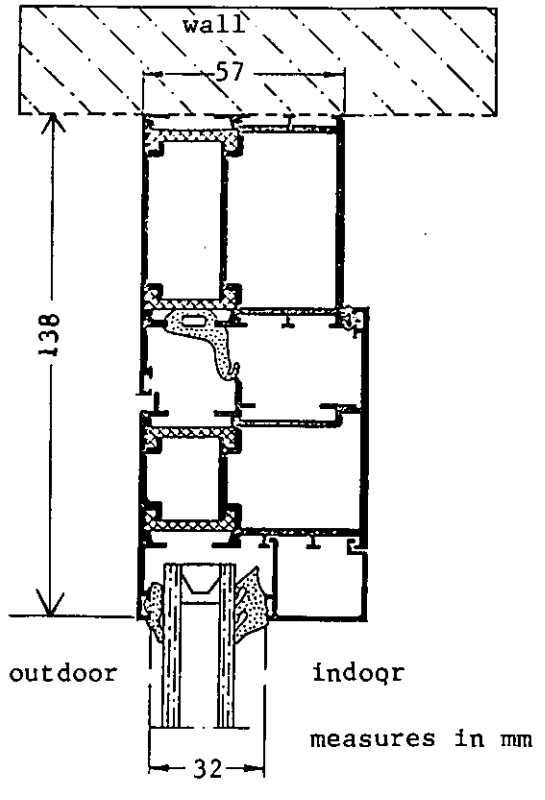


Figure 5: Example of insulated aluminium frame with thermal breaks ([5]).

It is particularly in the Do It Yourself sector that these systems are popular and e.g. in situations where existing windows are preserved to retain the character of the appearance of the window. By installing an additional secondary glazing at relatively low costs, other improvements may be achieved (acoustic insulation, air tightness). Disadvantages may be cleaning, condensation and IR-transparancy of certain plastic materials.

d. Commercial sector

In the sector of commercial and institutional buildings only few figures are available, although in all countries it is clear that aluminium frames have a high share of this market; for instance in Switzerland the insulated aluminium frames count for roughly 45 percent and wood/metal combinations for about 25 percent. Wooden and plastic frames can be found in only 5 percent of the new buildings in this sector in this country. Also steel frames can be found.

e. Quality control

The organisation of quality control for frame materials and products differ from country to country. In Germany for instance manufacturer organisations have set up quality control systems for window types and window production (RAL quality signs). In Norway nearly all windows are made under the quality control system of the Norwegian Door and Window Control (NDVK), including all parts of the window (wood, painting, glue, glazing, weather strips and metal parts).

Quality control concerning air and water tightness exists in all participating countries.

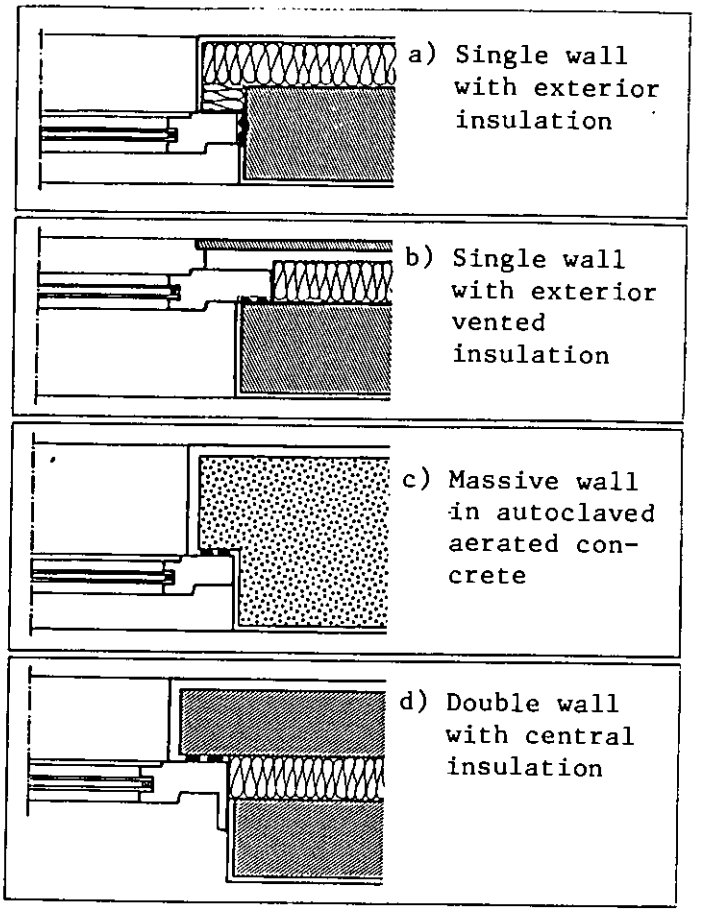


Figure 6a: Main wall constructions and window mounting procedure.

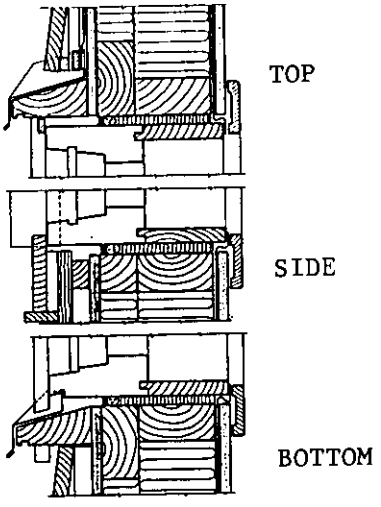


Figure 6b: Idem; timber frame walls ([9]).

3.2. General frame design

In the 19th century the prevailing window type in countries like the United Kingdom and the Netherlands was the vertical sliding window. In Belgium the last few centuries the window has consisted of a fixed light at the top and two smaller glazed parts opening towards the inside.
In the second half of that century in Germany double-winged swing windows were used, with a center mullion and a height of 0.90 - 1.20 m. Due to the room height a top window element was added. During the first half of the 20th century the trend was to keep the window-area free of construction elements. So the center mullion disappears more and more. Living rooms in Germany then were provided with double (box-type) windows. All other rooms had single glazed windows. Since 1930 double-operating windows exist.
In the Netherlands the 19th century window was succeeded by a window divided into three parts, a large unmovable part and next to this a combination of two smaller windows: a swing window with a fanlight above it, both opening to the outside. In the UK opening lights are either at the top or on one of the sides.

Most countries show a large diversity of framings, but e.g. in the USA double hung and sliding windows are probably the most popular types. As opposed to the situation in e.g. the Netherlands side hung windows in e.g. Belgium are opening to the inside.
Another striking difference observed when comparing the various countries is the way the window is mounted: in the Netherlands the windows are put into place and masonry cavity walls are built around them. In most other countries windows are mounted after the wall has been finished. In Switzerland for instance the mounting is done from the inside (figure 6) and the window is mostly kept in one plane with the interior wall surface (40%). In e.g. the Netherlands and the UK the windows are usually glazed when the main construction work is completed; in Norway for instance most windows are factory glazed.

Most countries report different techniques in commercial and institutional buildings; due to both the different architectural approach (e.g. curtain walls, window strokes) and to the often less traditional types of framing materials.
Also in dwellings new materials lead to new types of windows and fitting techniques, like the double aluminium or plastic horizontal sliding sashes (the Netherlands, figure 7) or the use of prefab concrete elements for the inner slab of the cavity walls, which in the Netherlands led to a fitting technique deviating from tradition: the factory glazed window is fitted from the outside to the concrete wall and a masonry wall is built on the outside around the window.

Figure 7a: Ventilation position.

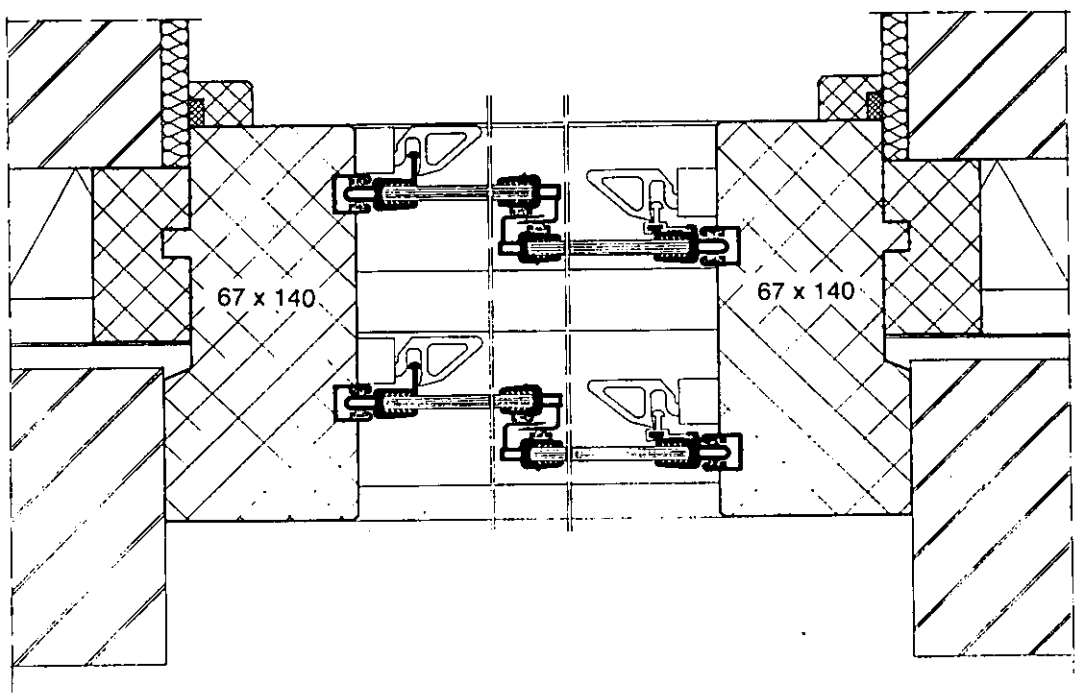


Figure 7b: Cross section, closed position.

Figure 7: Example of new design types: twin set of single horizontal sliding sashes (the Netherlands).

In most countries the window area is back where it was in the 1950s and before (the Netherlands e.g. about 15 m^2 per dwelling). During the 1960s the window areas were increased drastically; the material was relatively cheap and the additional daylighting was appreciated.
During the 1970s the area decreased again, a.o. because of the new insulation demands.

In the USA the use of skylights is reported as having increased in popularity over the last few years; the primary attraction of the traditional plastic dome or newer flat glass skylights is probably that they provide more light and a more pleasing space in the home. They are available with multiple glazing; clear, tinted, or diffusing material; may be operable for ventilation; and some are sold with interior blinds or shades.
In the UK the installation of "patio doors" in the renovation sector has expanded rapidly in recent years. These fully glazed (safety glass) sliding doors with aluminium frames often replace windows or form the glazing of an extension room added to the house. The latter idea to catch the sun is nowadays also found again in Belgium where there is a strong tendency towards the construction of a so-called veranda on the rear wall of houses.

3.3. Glazing

a. Residential buildings

It is not surprising that the traditional window in countries with moderate climates has single glazing. For these countries the majority of the buildings is still single glazed despite growing renovation activities.

Dwellings built at this moment in UK and the Netherlands still have a significant share of single glazing. In the UK about 80% is still single glazed, which is permitted provided the maximum window does not exceed 12% of the perimeter wall area; the other 15% are double sealed glazing units; in the UK there is also a growing tendency to apply safety glass (laminated or toughened) because of new regulations. In the Netherlands single glazing is still permitted in dwellings except for living rooms and kitchens;

this means that only about two-thirds of the windows in new dwellings is double glazed. In Italy all recent windows are double glazed, with the exception of the southern part of the country.

In Belgium, Switzerland and Germany all or nearly all new windows have double glazing. Some are coated and some even have triple glazing.

For new windows in Norway triple glazing or double with low-emissivity coating is compulsary, most of them are sealed units.

The situation in the USA varies widely with the climates, but even in the southern zones there is a major shift from single to double glazing, mainly as sealed units. Triple glazing has a share of 5-10 percent, but this figure will probably not increase, perhaps even decrease because manufacturers are beginning to offer double glazing units with low-emissivity coatings.

As mentioned before, in the replacement sector add-on units, many of these with plastic film or sheet products, have increased in popularity in various countries (USA, the Netherlands, UK).

b. Commercial sector

For the commercial and institutional sector only statistics from Switzerland are available. As could be expected in this sector more windows are applied with solar absorbing or reflecting glazings, although the percentage is still low (6%).

The percentage of triple glazing in this sector in Switzerland is much higher: 28% and only 6% is single glazed.

The USA reports the wide-spread use of tinted and reflective glass in non-residential constructions, but also in the southern third of the country with greater frequency in residential buildings.

c. Sealed units

The majority of sealed units of multiple-glazing have aluminium spacers with primary butyl and secondary polysulphide or silicone sealing.

The glazing of sealed units is critical. In the Scandinavian countries drained glazing is always used, whereas other countries tolerate fully bedded glazing systems with non-setting mastics.

Most countries have some kind of quality control system for sealed units with double glazing.
The majority of all sealed units produced or on the market are subjected to an external quality control. In most countries the quality control is voluntary.
The main difference between the countries is the organisation of responsibilities.
For the EEC-countries (via the Union Europeenne pour l'Agréement technique dans la construction (the UEAtc) attempts are being made to harmonise quality control at the international level.

3.4. Night insulation and solar shading devices

The use of blinds and shutters varies widely from country to country. This kind of provision is used for reasons of security, privacy, solar shading and/or thermal insulation.

In Italy external roller blinds are found practically everywhere in the residential sector, except in case of particular architectural requirements or traditions (mountain villages, historical city centers) where hinged shutters are applied. The roller blinds, mostly plastic, sometimes wood or aluminium, are used as night time insulation and darkening and also as solar shading devices, in which case they are partially lowered.

In sharp contrast to this, external roller blinds are almost unknown in the Netherlands, where hinged shutters used to be the traditional protection during night time, until they disappeared in the 19th century.

In its neighbour countries Belgium and Germany a different trend can be found: the hinged shutters have been maintained and partially succeeded by wooden roller blinds in the beginning of the present century. Since 15 years wooden roller blinds disappear more and more and plastic and aluminium substitute the traditional material. In Germany the roller blind market in 1984 was divided into 70 percent plastic and 30 percent aluminium. The use of wood, in 1972 still 10 percent of the market, has almost disappeared. In Belgium 30 percent of new dwellings is provided with roller blinds. Also on the retrofit market added roller blinds are popular in this country.

A similar situation can be found in Switzerland: roller shutters and venetian blinds are both found in about 25 percent of the new dwellings. These shutters and blinds are used both for night insulation and for solar shading.

In the Netherlands interior venetian blinds are commonly found, but also exterior screens, added by the inhabitants as a necessary, more efficient solar shading, for instance in highly glazed appartment buildings. Venetian blinds with closed slats sometimes replace curtains as night insulation. In many Dutch living rooms, however, night insulation provisions are installed but never used.
In the USA in the late seventies many new insulating and shading products appeared for interior and exterior use. Many had good potential performance but were costly, hard to operate, and not visually pleasing.

Over the past five years, manufacturers of traditional curtains, drapes, blinds, etc., have offered more energy-saving features with products that already have market acceptance. Several European products (e.g. exterior roller shutters and operable blinds) are being marketed in the US. The growth rate is high, but the absolute numbers are still very small. The majority of these systems, even in new constructions, are added to the window, rather than integrated into the window system.

In the non-residential sector mainly indoor venetian blinds are used.

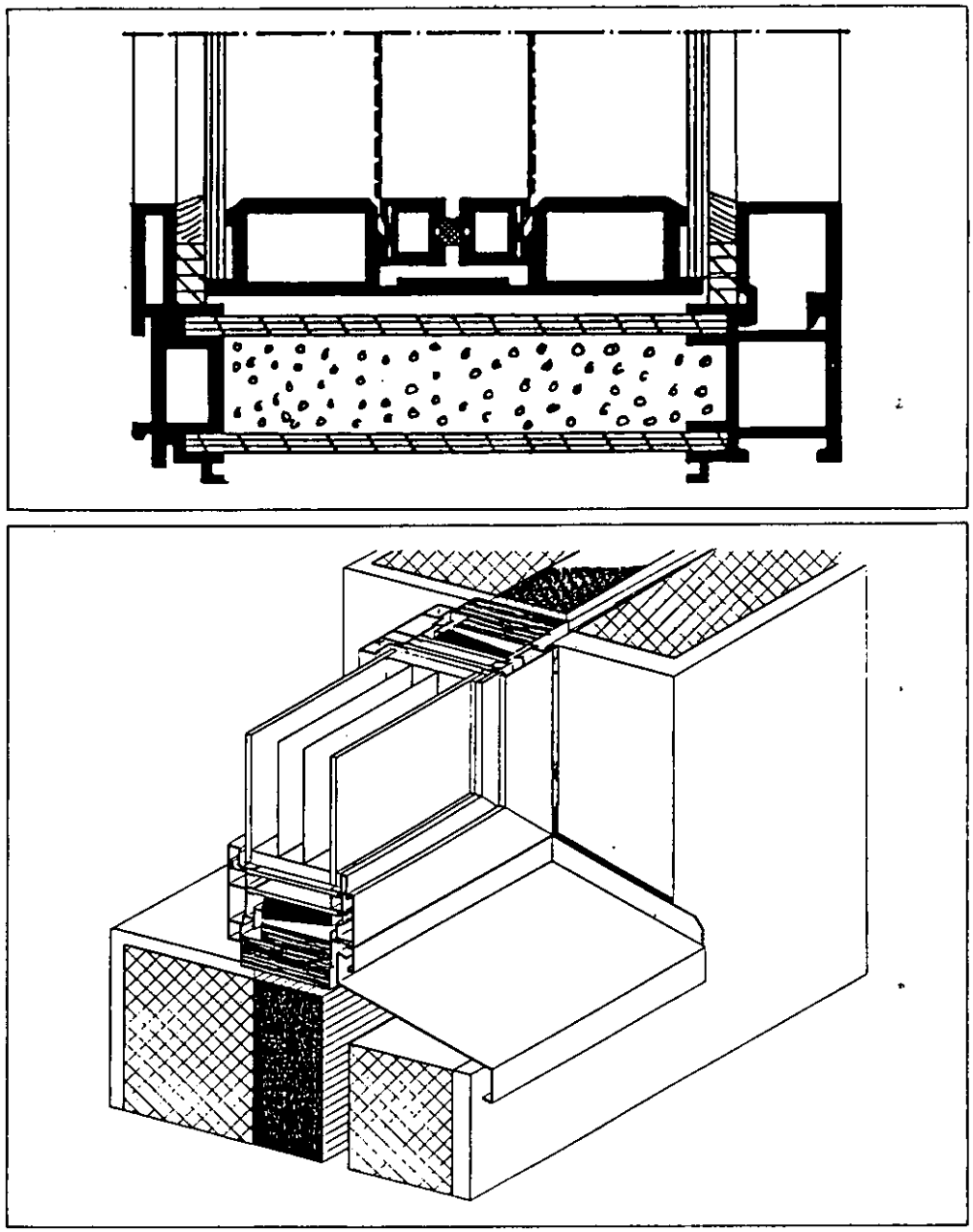
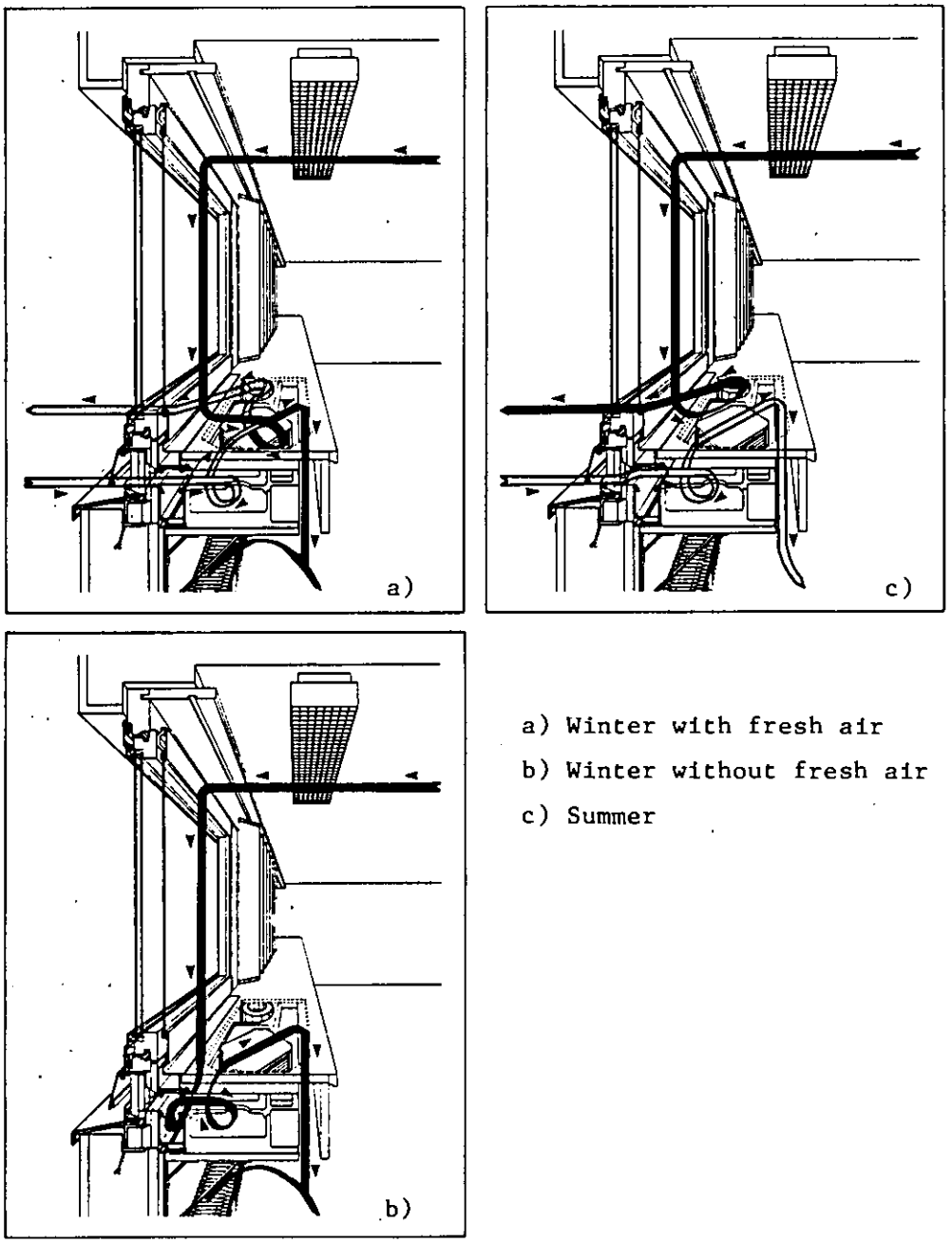


Figure 8: Example of innovative design: double glazing with two low-emissivity foils ([1]).

4. FUTURE DEVELOPMENT

In the near future energy saving and durability will also dominate the development of windows and window components.
Wood is still the cheapest frame material; one can presume that new preservation methods will be developed to prevent rot formation in construction (e.g. Norway) and better quality timber will be used to combat the use of alternative frame materials, particularly PVC (e.g. UK). Another way to go is to combine materials, to combine the advantages of all material in window construction (e.g. Norway, Germany). Knowledge and experience with current timber window frame sections in Norway has developed to the extend that the opinion is that further improvement is unlikely.

Concerning glazing materials it is expected that single glazing will continue to be replaced by double glazing (e.g. UK, the Netherlands). A growing market is expected for glazing with low-emissivity coatings combined with high solar transparency. In the UK the demand for low-emissivity glass in double glazed units started in the replacement window business, but will spill into the new housing market. In Germany it is believed that the development of coatings is limited with respect to the colour: German domestic consumers want neutral colour coatings.
In the USA glazing with low-E coatings is emerging as a major product. Several manufacturers in the US are replacing their triple glazed product lines with low-E products. Most major glass manufacturers now produce a low-E product. These are primarily multi-layered sputtered films but pyrolitic coatings are expected to appear on the market in 1986. Low-E coatings on plastic suspended in a double glazed unit are offered by several manufacturers but have not captured a large share of the market. Windows with anti-reflective (high transmission) plastic films stretched in the air space are also marketed in the USA.



a) Winter with fresh air
b) Winter without fresh air
c) Summer

Figure 9: Example of innovative design: exhaust air window ([1]).

In other countries too the market for triple glazing is not expected to grow. The manufacturing process of triple glazed units is expensive and the seals are vulnerable; the additional weight also requires more rigid frames, stronger fittings and is more difficult to assemble.

Low-E, gasfilled double glazing units will probably have a growing market, but quality control with respect to the sealing and the actual composition of the gases is necessary. At the moment there are wide differences in quality (e.g. Germany).

In the US because of skepticism concerning the tightness of gasfilled units, although manufacturers are discussing the use of gasfills, few have ventured into this area with actual products.

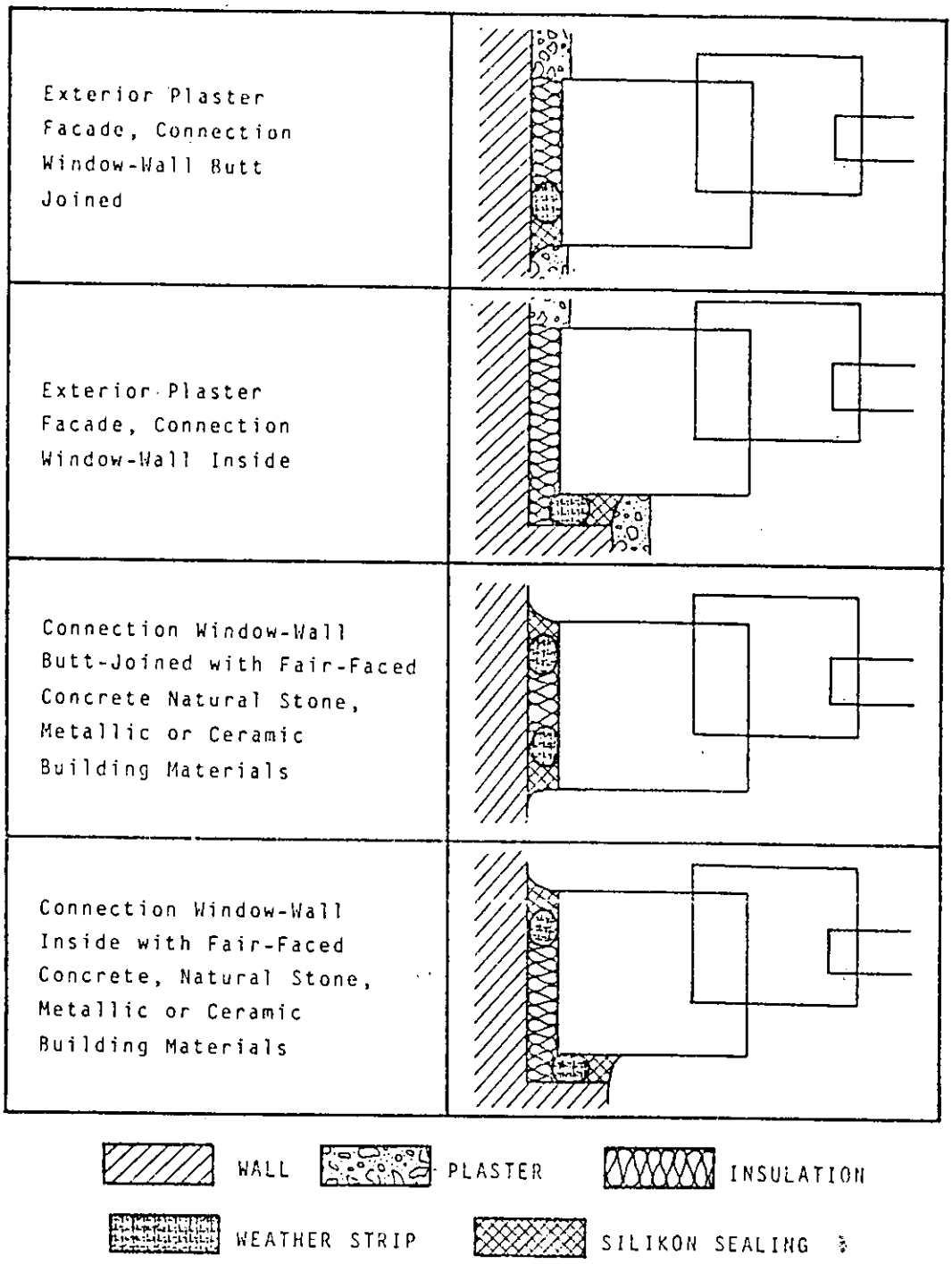
One may expect a conflict between temporary and permanent heat insulation. The result should be left to the free market forces, but it is expected (e.g. Germany) that the trend is towards 'temporary' insulation (blinds etc.) in dwellings and towards 'permanent' insulation in the non-residential sector.

In the UK safety standards will continue to be applied more rigorously thus increasing the demand for toughened and laminated glass and in some cases polycarbonate glazing.

It is not expected that currently rather uncommon energy saving devices, e.g. automatic insulating shutters, insulating blinds, etc., will find a rapidly increasing use, in either new dwellings or as add on solutions in existing housing, unless stimulating measures are taken.

Other auxiliary devices such as foils, Silica Aerogel, etc. should be judged cautiously. Regarding their long-term effect, the materials are rather unknown, and there is not yet any practical experience.

However, if these innovative solutions stand the tests there are obviously good possibilities.



Examples for:
- Expected expansion of Joints ≤ 4 mm
- Stress groups according DIN 18055, Part 2: B, C
- Vibrations: heavy live loads
- Stress group: 2
- Sealing by means of joint sealant.

Figure 10: Some methods of connecting the window to the building.

From Switzerland two typical innovative designs are presented ([1]), a 'passive' and an 'active' solution for energy conservation:

1. an integrated window/façade system with extreme low thermal transmission properties (U = 0.6 W/m^2K); the window consisting of a double glazing unit with two low-emissivity foils suspended in the air space and a frame with U-value of 0.90 W/m^2K (figure 8);
2. an integrated ventilated window ('climate window') in which exhaust air can be ventilated through the cavity between inner and outer panes to increase the inner pane temperature. The exhaust air is then led through an integrated heat exchanger to preheat the fresh air for natural ventilation of the room. Other flow directions can be chosen to deal with e.g. summer situations (figure 9).

As the conductance of the glazing unit is reduced, more attention is going to be paid to edge effects: spacers of double glazing units, aluminium sashes and frames and wall connections. In Germany and Belgium the thermal bridges from the latter have already led to guiding rules on the placement of window systems; these rules should be made obligatory in every situation (figure 10).

In some countries it is expected that weather seals will improve in the future.

This means better lasting elasticity, longer durability under climatic strains and better resistance to deformation and shrinkage. The use of more sophisticated hardware associated with windows will probably increase.

Very tight windows can worsen condensation problems in already tight buildings. In several countries the solution tends to a mechanical ventilation system with in some cases a heat recovery system. Separate ventilation openings have become common as integrated parts within the window frame; related to these provisions are aspects of acoustical and thermal insulation.

Finally, there is an increasing demand for windows with a better acoustic performance in both new and existing housing (e.g. UK, the Netherlands) due to concern with a pervading noise climate from road traffic and aircraft in the surroundings of major airports. This will be reflected by improving frame design and glazing with 'acoustic' units incorporating special solutions (e.g. laminates, gasses).

5. TABLE WISE SURVEY FOR QUICK COMPARISON

In table 1 the situation in each country for the residential building sector is characterised in a few words to allow quick comparison.

COUNTRY			BELGIUM
"TRADITIONAL" (PRE-WWII)	Frame	Material	Wood 100%
		Mounting	Jamb in masonry Joint between frame and masonry with mortar
		Design	Double opening = single opening (small frame)
	Glazing		Single glazing
	Shading, night insulation		Roller blind + hinged shutters
POST - WWII TRENDS	Frame	Material	Wood (75%) from 1960: aluminium + steel (25%) became rather important
		Mounting	Jamb in masonry + lateral joint in plastic packing
		Design	Large single opening - double opening - French opening
	Glazing		Single glazing, use of double glazing - rather small
	Shading, night insulation		Roller blinds
NEW TRENDS POST 1973	Frame	Material	Wood (50%) - plastic frames (mainly PVC) (25%) and aluminium with thermal barrier (20%) others (5%)
		Mounting	Elastical mastic + foam with and without jamb on the surface of the façade
		Design	Augmentation of the vertically/ horizontally hinged windows / Regression of the double-light
	Glazing		Double glazing more and more the last years 90 ... 95%, small market improved double glazing
	Shading, night insulation		Roller blind
	Retrofit		External placed roller blind
FUTURE			Reduction of glazing surfaces

COUNTRY			GERMANY
"TRADITIONAL" (PRE-WWII)	Frame	Material	Wood
		Mounting	From inside, after wall was finished
		Design	Box-type window, single operating window
	Glazing		Single glazing
	Shading, night insulation		Side-hung shutters
POST - WWII TRENDS	Frame	Material	Wood, aluminium
		Mounting	From inside, after wall was finished
		Design	Box-type windows, double operating windows, single operating windows
	Glazing		Single glazing
	Shading, night insulation		Wooden roller blinds, overhang (aluminium, steel)
NEW TRENDS POST 1973	Frame	Material	Wood, aluminium, plastic, (aluminium + wood)
		Mounting	From inside, after wall is finished
		Design	Single operating windows
	Glazing		Double glazing; triple glazing, coated glazings
	Shading, night insulation		Roller shutters (wood, plastic, aluminium) Slatted blinds (aluminium)
	Retrofit		Plastic with insulating glazing
FUTURE			- Coated glazing - Foil-window

COUNTRY			ITALY
"TRADITIONAL" (PRE-WWII)	Frame	Material	Wood
		Mounting	Single and double, separate sashes
		Design	
	Glazing		Single glazing
	Shading, night insulation		Curtains, roller blinds
POST - WWII TRENDS	Frame	Material	Wood, aluminium
		Mounting	Single and double, separate sashes
		Design	
	Glazing		Single glazing
	Shading, night insulation		Curtains, venetian blinds, roller blinds
NEW TRENDS POST 1973	Frame	Material	Wood, aluminium, plastic
		Mounting	Single sash
		Design	Air tight, thermal breaks
	Glazing		Double glazing
	Shading, night insulation		Curtains, venetian blinds, roller blinds
	Retrofit		Double separate sashes
FUTURE			

COUNTRY			THE NETHERLANDS
"TRADITIONAL" (PRE-WWII)	Frame	Material	Wood, some steel (app. bldgs.)
		Mounting	
		Design	Vertical sliding
	Glazing		Single glazing, fully bedded
	Shading, night insulation		Interior drapes for privacy/ shading; exterior awning, no exterior shutters
POST - WWII TRENDS	Frame	Material	Soft wood
		Mounting	Windows positioned first, cavity-wall erected afterwards
		Design	Divided in three parts: 1) large fixed, 2) side hung, 3) top hung, fan light
	Glazing		Single, uncommon double
	Shading, night insulation		Interior blinds, curtains, 50% used in night time, awnings
NEW TRENDS POST 1973	Frame	Material	Hard wood, sometimes in combination with PVC frame for sliding
		Mounting	As POST - WWII, some complete windows in prefab. walls
		Design	Decreasing window areas
	Glazing		Double in livings rooms, single in bed rooms, drained
	Shading, night insulation		As POST - WWII, some vertical louvres for decoration, exterior
	Retrofit		PVC-frames, double glazed, D.I.Y. add-on panes (glass-acryl)
FUTURE			- Increased Low-E - Possible: Various passive solar designs

COUNTRY			NORWAY
"TRADITIONAL" (PRE-WWII)	Frame	Material	Wood
		Mounting	Side hung windows, divided in smaller felt
		Design	
	Glazing		Single glazing
	Shading, night insulation		n.a.
POST - WWII TRENDS	Frame	Material	Wood
		Mounting	Quality control comes into use and mounting of glazing in factory
		Design	Frames with drained rabates, larger felts of windows
	Glazing		Single + extra winter glazing, from 1960 sealed double unit
	Shading, night insulation		Curtains
NEW TRENDS POST 1973	Frame	Material	Wood, but in larger buildings aluminium and PVC
		Mounting	Different type of frames mostly side hung or turn round types
		Design	Aluminium frames with thermal breaks
	Glazing		Sealed unit, triple glazing or double with sealed coating
	Shading, night insulation		Curtains
	Retrofit		Wood with 2-3 layers or PVC-window in larger buildings
FUTURE			- Use of better low-E coatings and gasfillings - Depending on economy and product possible insulation shutters (int./ext.)

COUNTRY			SWITZERLAND
"TRADITIONAL" (PRE-WWII)	Frame	Material	Wood
		Mounting	Inside
		Design	Side hung casements
	Glazing		Single with an additional single glazing during the heating season
	Shading, night insulation		Mainly storm shutter
POST - WWII TRENDS	Frame	Material	Wood
		Mounting	Inside
		Design	Side hung casements
	Glazing		Double glazing, start of insulated double glazings since 1955
	Shading, night insulation		Roller blinds
NEW TRENDS POST 1973	Frame	Material	Wood: 66%; Wood/metal: 20%; Plastic: 14% (statistics 1983)
		Mounting	Frame in the same plane as the insulation of the wall
		Design	Side, side and top hung casements
	Glazing		Double glazing: 65%; Triple glazing 24%; double coated glazing: 11% (statistics 1983)
	Shading, night insulation		Roller blinds 60%; venetian blinds 20%; storm shutter 20%
	Retrofit		Wood, wood-metal and plastic frames with double (coated or not) and triple glazing
FUTURE			- Increased use of triple glazing - Increased use of low-emissivity coatings - Increased use of plastic frame

COUNTRY			UNITED KINGDOM
"TRADITIONAL" (PRE-WWII)	Frame	Material	Wood
		Mounting	Fixed after construction of masonry
		Design	Vertical sliding sashes / casement
	Glazing		Single, simple putty glazed
	Shading, night insulation		Internal curtains
POST - WWII TRENDS	Frame	Material	Wood
		Mounting	Fixed after construction of masonry; sometimes during construction
		Design	Fixed frame / opening side and top hung fanlights
	Glazing		Mostly single, some insulated glazing units, fully bedded with non-setting mastics
	Shading, night insulation		Internal curtains; venetian and roller blinds
NEW TRENDS POST 1973	Frame	Material	Some PVC; mostly wood
		Mounting	Some factory glazing
		Design	Patio doors - safety glass in doors and door surroundings
	Glazing		Increasing double glazing rising from 15% in new buildings
	Shading, night insulation		Internal curtains, blinds
	Retrofit		Big retrofit market aluminium and some PVC - all double glazing
FUTURE			- Growing use of Low-E with Argon-gas - Management - Sunspaces

COUNTRY			USA
"TRADITIONAL" (PRE-WWII)	Frame	Material	Wood
		Mounting	Fully bedded
		Design	Double hung (both sashes, vertical sliding
	Glazing		Single; Storm windows common northern part in single family
	Shading, night insulation		Interior blinds/drapes for privacy/shading universal; insulating and exterior systems uncommon
POST - WWII TRENDS	Frame	Material	Aluminium frames
		Mounting	No thermal break; drain, weep holes for storm windows
		Design	Sliding, casement
	Glazing		Insulating glass, integral storm windows, available but uncommon
	Shading, night insulation		Increasing use of venetian blinds
NEW TRENDS POST 1973	Frame	Material	Aluminium, plastic claddings; Wood/plastic claddings
		Mounting	Thermal breaks; improved weather strips; better quality control
		Design	Sliding, casement, double-hung
	Glazing		Double glazing in new construction northern 2/3 of country; some Low-E; increased use of skylight
	Shading, night insulation		Some exterior shutters, more interior insulation with shading, privacy
	Retrofit		Interior storm windows, insulating shades; some replacement of single glazed windows for double
FUTURE			- Increased use of Low-E - Increased int./ext. insulation systems - Possible: Variable transmission windows, spectrally selective glazing systems, reflective / absorbing single glazing, southern 1/3 of country

REFERENCES

[1] "Fenster und Fenstersysteme, Stand der Forschung und Entwicklung",
Gay, J.B., Frank, Th., Keller, B., a.o.,
Ecole Polytechnique Federale de Lausanne,
Lausanne, Switzerland.
May 1984.

[2] "Deutsche Mitarbeit bei IEA-XII, Zusammenstellung bisheriger Fensterkennwerte, Test- und Berechnungsmethoden",
Schmid, J., Krebbers, J.,
Institut für Fenstertechnik e.V.,
Rosenheim, FR Germany.
June 1984.

[3a] "Deutsche Mitarbeit bei IEA-XII, Dokumentation vorhandenen Fenstersysteme,
Schmid, J. Krebbers, J.,
Institut für Fenstertechnik,
Rosenheim, FR Germany.
June 1984.

[3b] "Windows and Window Systems - State of Technology and Development",
Schmid, J., Krebbers, J.,
Rosenheim, FR Germany.
January 1985.

[4] "The Renovation and Replacement of Windows in Buildings",
Owens, P.G.,
Pilkington Flat Glass Ltd., Technical Advisory Service
paper at Anglo-Finnish Techn. Coop. Joint Seminar.
November 1983.

[5] Kasper, Müller, Rudolphi, Wagner:
Theoretische Ermittlung des Waermedurchgangskoeffizienten von Fensterkonstruktionen unter besonderer Berücksichtigung der Rahmenproblematik, Forschungsvorhaben 02429, Bundesanstalt für Materialprüfung, Berlin, 1985.

[6] Algemeine Bauzeitung 52 (1982), nr. 50, S.9.

[7] Constructional details and joinings (EG80), NPR 3670 B, Wooden window frames with windows, doors, glass and other wall panels to be placed in façade openings. Code of practice for the manufacturer.

[8] Building detail sheet, A 533.134, Norwegian Building Research Institute, 1982.

[9] Building detail sheet, A 523.701, Norwegian Building Research Institute, 1984.

APPENDIX 1

The following participants were involved in this part of the research project:

NAME	AFFILIATION	ADDRESS	COUNTRY
P. Wouters, J. Dubois	Belgian Building Research Institute	Lombardstraat 41 B-1000 BRUSSELS	BELGIUM
H. Erhorn, R. Stricker, M. Szerman	Fraunhofer Institut für Bauphysik, Dir.: Prof.Dr.-Ing.habil, K.A. Gertis	Nobelstrasse 12 D-7000 STUTTGART 80	FR-GERMANY
R. Brunello	Istituto di Fisica Tecnica	Viale Ungheria 43 I-35100 UDINE	ITALY
R. Zecchin	Istituto di Fisica Tecnica Università di Padova	Via Marzolo 9 I-35100 PADOVA	ITALY
H.A.L. van Dijk, K.Th. Knorr	TNO Institute of Applied Physics (TPD)	Stieltjesweg 1 2600 AD DELFT	THE NETHERLANDS
A. Nielsen	Norwegian Building Research Institute	Högskoleringen 7 N-7034 TRONDHEIM-NTH	NORWAY
J.B. Gay	Ecole Polytechnique Féderale de Lausanne (EPFL)	LESO CH-1015 LAUSANNE	SWITZERLAND
T. Frank	EMPA Dübendorf Section Building Physics	Überlandstrasse 129 CH-8600 DÜBENDORF	SWITZERLAND
P.G.T. Owens	Pilkington Glass Ltd.	Prescot Road, St. Helens, MERSEYSIDE WA10 3TT	UNITED KINGDOM
J.H. Klems, S. Selkowitz	Lawrence Berkeley Laboratory	1, Cyclotron Road BERKELEY, CALIFORNIA	USA