SURVEY OF THE EXISTING BUILDING STOCK TO ASSESS THE PASSIVE SOLAR POTENTIAL

FINAL REPORT

by

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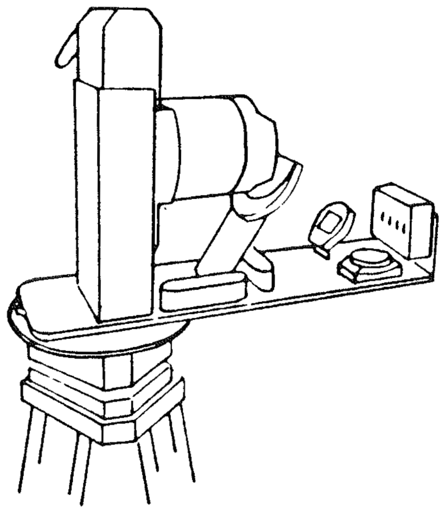
(Approved version)



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PREFACE

The utilization of passive solar energy has become a more widely known feature among architects and building planners in the recent years. The passive solar measures do normally not involve as many technical installations as active solar measures and are therefore easier adaptable to traditional building design and the general apprehension of a building. However the passive solar measures widely differ in physical concept. In some cases they only call for extended emphasis on already comprehended features, in others they involves totally new thinking. A passive solar measures is an integrated part of a building specificly of the thermal envelope and the concept therefore opens up for many new interesting solutions, but also requires careful investigation of the impact on the thermal balance and human comfort in the building.

The purpose of this investigation is to focus on the possibilities of utilization of passive solar features in the existing building stock. The idea was to get an overall view of the utilization possibilities, to compare the different measures and to examine the constraint that might limit the possibilities. It is believed that the existing building stock has a great potential for utilization of passive solar energy and introduction of this feature is an important step towards reduction of the consumption of fossil fuels.

The investigation has been funded by the Commission of the European Communities and carried out by the Thermal Insulation Laboratory, Technical University of Denmark, under contract EN3S-0038-DK (B), as part of the CEC Non-nuclear Energy - Solar Energy Programme. The work has been carried out by Ole Olesen, Michael Mollgaard and Lars Olsen, civil engineers, M Sc.

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1. INTRODUCTION

In the last 10-15 years large savings in energy consumptions for heating have been achieved in Denmark. The savings have primarily been obtained by energy conservation and changing to more energy conscious habits. There has only been little emphasis on the use of passive solar measures. In many energy rehabilitated buildings it is difficult to reduce energy consumption further by conservation techniques, but provision of passive solar systems seems to have a large potential for further savings.

Introduction of a new technology on the market is always difficult. Passive solar systems incorporate an integrated functionality. The systems have to act both as a building component and as a part of the heating system of the building. This dual function makes the responsibilities more difficult to apply in a project. Manufacturers of building component do normally not think in terms of more advanced heating systems and mechanical engineers designing heating systems do not normally have experience with design of buildings.

Not only newer houses are in question for passive solar utilization, but it is believed that the existing building stock has a great potential.

The purpose of this investigation is to focus on the possibilities of utilization of passive solar features in the existing building stock. The aim is to get an overall view of the utilization possibilities, to compare the different measure's ability to adapt the existing building stock and to examine the constraint that might limit the possibilities. As the passive solar measures are an integrated part of a building the concept therefore opens up for many new interesting solutions, but requires also careful investigation of the impact on the thermal balance and human comfort in a building.

1.1. OBJECTIVES

In new houses passive solar features can very easily be incorporated when considered in an early planning stage. But many different passive solar measures can be applied in various extent to the existing building stock. The most important are :

- Changed window area.
- Improved window construction. Better glazing or movable insulation etc.
- Attached sunspaces.
- Solar walls.
- Roof-space collectors.
- Increase of heat storage capacity in building.
- Reduction of the overshadowing effect.

The different measures vary much in the requirements to the building, installation and in the expected benefits.

1.2. CONSTRAINT FOR APPLICATION OF PASSIVE SOLAR SYSTEMS

One of the reasons for performing this investigation is to enlighten the most obvious physical constraint for introduction of passive solar features. The purpose is to:

- Get a picture of the size of the limiting constraint in order to get an overall view of the physical possibilities of utilization of passive solar energy in the existing building stock.

- Encourage the most promising passive solar features on the basis of their capacity to adapt to the existing building stock.

- Look for constraint that might be eliminated in newer buildings or eliminated in existing buildings if exceptions for e.g. maximum building percentage can be obtained.

The physical constraint and possibilities are very much depending on the proposed passive solar measures. In general the most important are:

- Constructional. The existence of components and materials usable for a proposed measure. The heat capacity e.g. in a building or part thereof is very important for all passive solar systems. Also structural problems can occur, when a measure requires intervention of the structural function of a part of the building.

- Required space in the building. For the measure itself and maybe belonging ducts and storage.

- Available solar energy. Orientation and overshadowing of usable facades and roofs.

- The use of the building and especially the use of the rooms in connection with the passive solar measures.

This study has focused on the physical constraint but there are many more as e.g.:

- Legislative (Energy planning).
- Architectural.
- Building preservation.

Legislative restrictions can be:

- Mandatory use of facade and roof linings.
- Maximum built-up area.
- Possibilities of escape in case of fire.
- Distance to boundary and streets.
- Maximum building height.

Other factors that might limit the introduction:

- Lack of knowledge.
- Limited experience.
- Resistance to unproven technologies.

2. INVESTIGATION PROCEDURE

The investigation has been carried out in the following steps :

- Defining parameters to be investigated.
- Selecting of sample.
- Gaining accept from inhabitants or owners to carry out the investigation.
- Investigating and collecting data.
- Analyzing collected data.

For the collection of data it has been necessary to get information from various sources:

- Deposited building plans.
- Heat inspection reports.
- On-site inspections.
- Photos taken on-site.

In order to do the collection of data in a systematical way standard forms have been used for all buildings:

- A main form containing all relevant information on geometry, energy use etc. (Appendix A).
- A photo form containing data extracted from the photos taken (Appendix B).

For the handling of data various computer programs have been used:

- A spread sheet program with the two standard forms implemented.
- A photo transforming program for transforming the photo data into usable information.
- Various programs for extracting and comparing data from all the investigated buildings.
- Program for calculation of the annual heating requirements and savings for the various measures.

All computer programs have been specially made for this project.

One of the purposes of this project was to analyze the collected data statistically defining typical buildings, which should be the basis of a design study of application of the different passive solar options. It has however been chosen to investigate all the buildings in the sample because:

- The number of investigated buildings 67 (174 households) is a little smaller than expected.
- Definition of typical buildings is very difficult, due to the various number of possible definitions.
- When analyzing the collected data, the use of a computer made it fairly easy to find evidence of possible application of the different passive solar measures and also to calculate the expected performances for most of the features.

The result is a wider investigation than originally aimed for, bearing in mind that the analyzed material only consists of the photos and data collected in the standard forms. No additional information has been collected to make case studies.

3. SELECTION OF SAMPLE

The aim has been to to select a group of buildings which fit the urban building stock in Denmark by terms of dwelling and age. The buildings have been divided into three dwelling types:

- Single family dwellings.
- Terraced and low rise, high density buildings.
- Multi-storey buildings.

On the basis of the main features of Danish building tradition the buildings have been divided by age into four groups:

	- 1939
1940	- 1959
1960	- 1969
1970	- 1979

General statistic material has been obtained for the survey area; Copenhagen and northern Zealand. This covers about a third of all households in Denmark.

STATISTIC MATERIAL :

Copenhagen and northern Zealand
Number of households : 697214

Fig 1 :

Number and relative number of households in different age and dwelling categories

Dwelling category	Year of construction			
	-1939	1940-59	1960-69	1970-79
Single family dwellings	53540 7.7 %	33685 4.8 %	40332 5.8 %	32647 4.7 %
Terraced and low rise, high density buildings	11196 1.6 %	26360 3.4 %	13087 1.9 %	22746 3.3 %
Multi-storey buildings	256873 35.8 %	96440 13.8 %	62072 8.9 %	48236 6.9 %

A group of 103 buildings covering about 230 households have been selected from the central heat inspection archives for investigation as the archives contain valuable information regarding insulation and heating source. The archives are regarded as fully representative of the total statistic material.

4. CORRESPONDENCE WITH OWNERS AND INHABITANTS

The on-site investigation has been necessary for registration of information which could not be gathered from deposited plans. This supplementing information regarded:

- Window construction. Glazing and overhang.
- Visual evaluation of solar facades and roofs (facades and roofs that might be suitable for application of passive solar measures).
- Overshadowing of solar facades and roofs.

The investigation has called for outdoor access to each property and it has therefore been necessary to obtain permission from owners/inhabitants to do so, even though the investigation didn't call for any participation or cause any inconvenience for the inhabitants. A letter with enclosed stamped addressed envelope was sent to each owner asking for this permission. In the letter was also a request for permission to publish pictures of the building and some minor important questions regarding use of window covering.
The described procedure had some problems which caused a relatively small number of replies. The sample of buildings had prior been selected from the heat inspection archives because these heat inspection reports contain some information regarding installed heating type, estimated annual heating requirement and estimated savings of proposed post-insulation. But because this central heat inspection is a fairly new procedure in Denmark and usually only performed in connection with house sales unfortunately many of the buildings had changed owners causing problems of addressing to the right persons. This problem is considered purely as local Danish and temporary.

5. MAIN SURVEY QUESTIONNAIRE

The survey questionnaire is the main sheet for gathering the information of interest in a systematical way. In appendix A a filled-out form is presented, with data from an example chosen together with comments on the different information in the survey questionnaire. The survey questionnaire contains information concerning:

- Basic shape and orientation of the building.
- Facade, window and living areas etc.
- Information regarding wall and window construction.
- General data; Address, owner and owner type etc.
- Overshadowing effect of investigated facades and roofs.

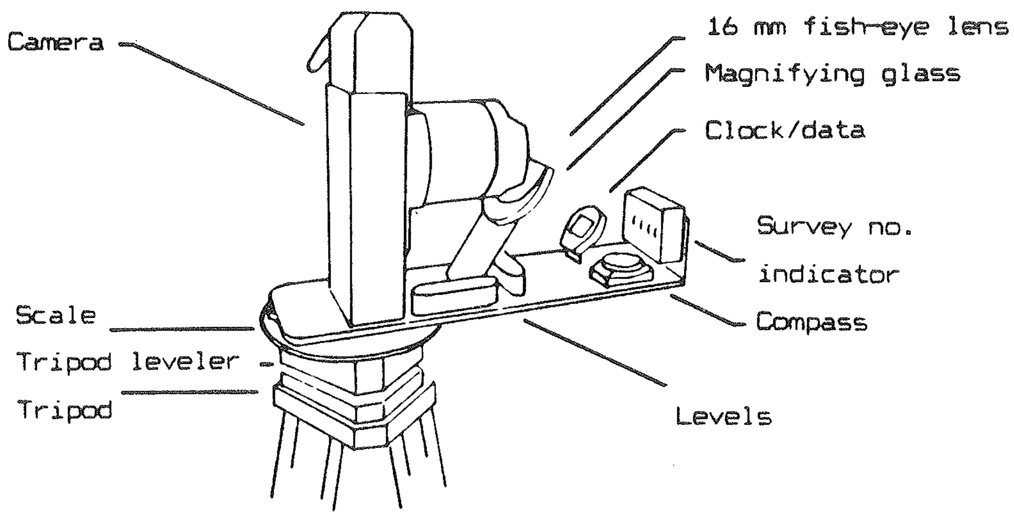
The information is gathered from various sources:

- Deposited plans.
- On-site investigations.
- Heat inspection report.
- Result of photographic investigation (On-site investigations).
- Reply letter from inhabitants.

6. PHOTO SURVEY

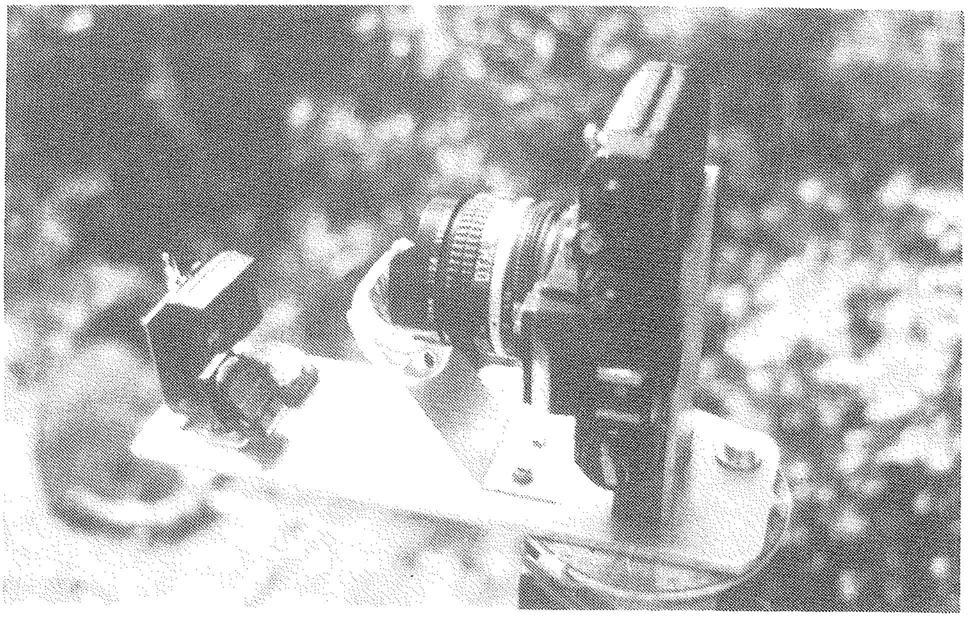
In order to determine the overshadowing effect from neighboring obstacles on a facade or roof a photographic method has been developed. Three pictures are taken in front of a facade using a specially made camera arrangement.

Fig 2. Camera arrangement



The magnifying glass secures that the clock, the survey number and the compass are in focus. The lens is a 16 mm fish-eye, f/2.8 which encompasses 86° horizontally and 128° vertically.

Fig 3. Photo of the camera arrangement



Procedure for the photography:

- The camera is placed centrally in front of the facade at approximately 1 m from the wall and leveled. The height of the camera above the ground and the distance to the facade is measured and recorded.
- The form for the photo survey is presented in appendix B. The camera is directed perpendicularly to the facade using a pole placed away from the camera (at the corner of the house) but at the same distance to the wall as the camera.
- Three pictures are taken; one perpendicular to the facade and the two others at + 60° and -60° to this direction.
- Approximate distances to major objects and the type of trees are recorded on a small plan drawing. The trees are divided into two types (deciduous and evergreens) because the overshadowing caused by deciduous trees is depending on the season.

Fig 4. The photo set-up

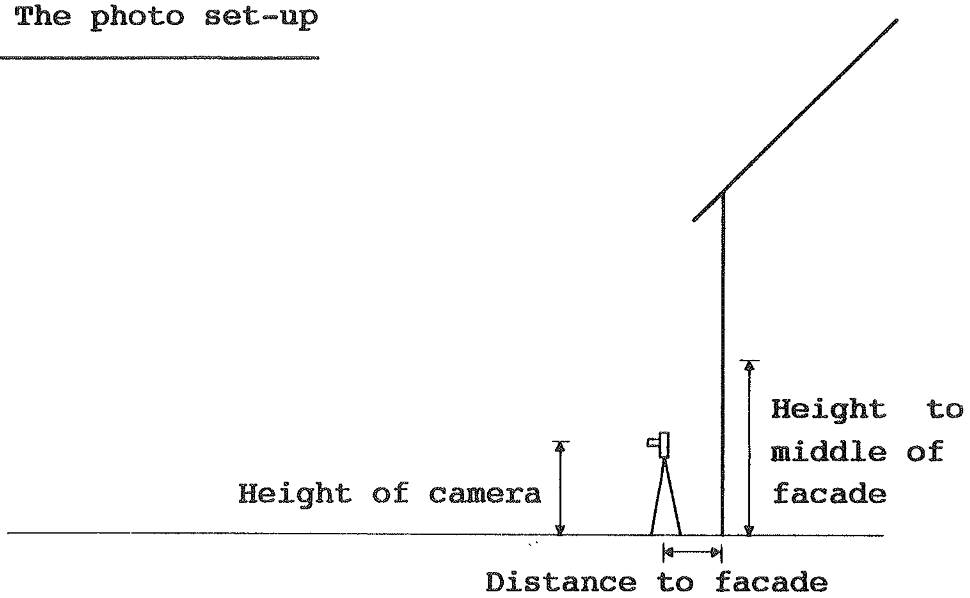
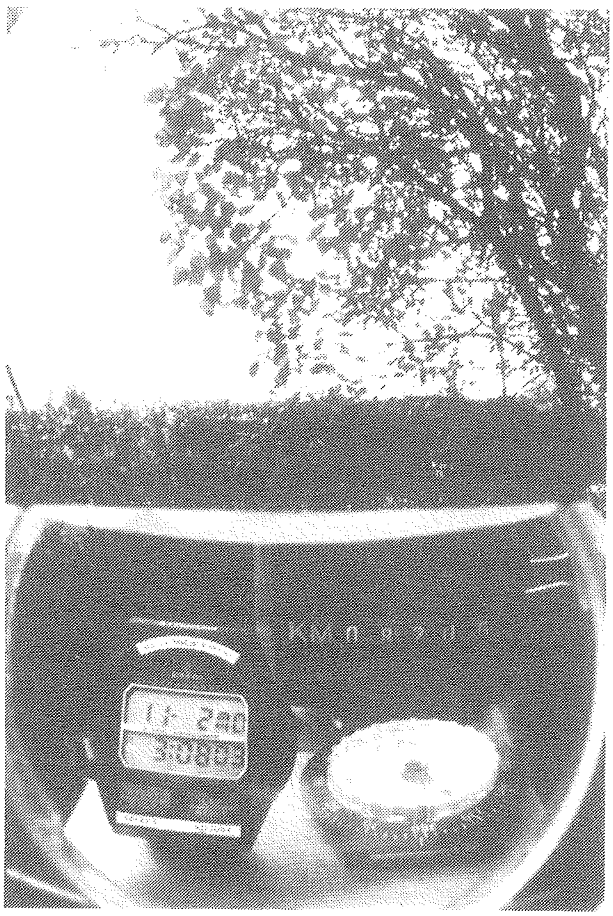


Fig 5. Example of survey picture

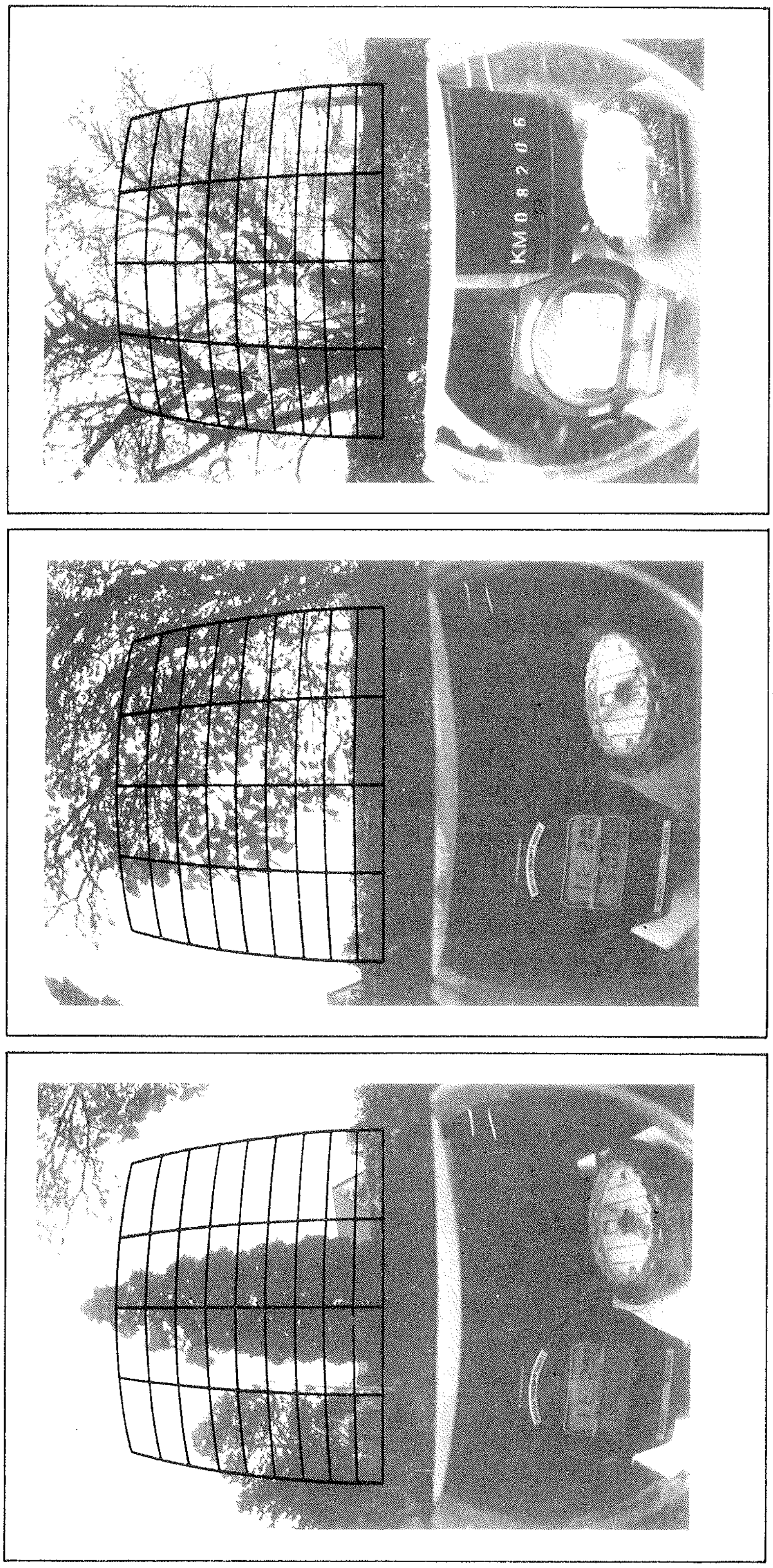


The upper part survey photo Fig 5. shows the overshadowing obstacles and the lower part contains information on time, data, survey/picture number and orientation.
It is the experience that it pays off to have the proper equipment; Standard forms, good measurement band and the camera mounted on a firm tripod with adjustable scale. The used camera arrangement is not standard and had to be especially made. The tripod used is a solid survey tripod as a photo tripod was found to be too unstable.
The described method has proved to be very efficient. The whole procedure does not take more than 10-15 min per facade.

Transforming pictures into comparable data:

The pictures are projected down on an overlay chart in the photo form. This chart has a grid with a distance between the lines of 15° horizontally and 5° vertically. The chart is made so it takes the optical transformation of the camera lens and projector into account. The photo form is showed in appendix B and the transformation is accounted for in appendix C. For each rectangular enclosure in the grid and with help of the plan drawing the percentage overshadowing is recorded together with information on the approximated distance to the object and a code if the object is a deciduous tree. With this measure some of the information in the pictures is lost, but it has been necessary to reduce the vast number of information withheld in a picture in order to have a manageable number of data. This way each facade requires recording of 312 real numbers and 156 tree codes. Of cause this sounds of much but by use of filled out standard forms and repeaters it generally does not require more than 20-30 numbers to be recorded. The operation only takes around 10-15 min.

Fig 6. Set of survey photos projected down on overlay chart with grid.



Transformation of data:

For each facade all the picture data is implemented on a computer using a spread sheet program. Again filled-out standard forms and repeaters are used which make the operation very easy. A filled out form is listed in appendix B.
Now the data can be handled in various ways. The best thing would be to make annual simulations of the solar irradiation and the overshadowing effect on the building. Maybe even for each window or part of a facade. But as the project deals with many kinds of passive solar measures it has been chosen to reduce all the overshadowing data to one comparable factor for each investigated facade or roof. Erwin Petersen (ref 6) has investigated the relative reduction of solar gain Fs in the heating season through a double glazed window for a facade oriented south, west, east, south +/-30° and south +/-60°. The result of this investigation is 7 solar charts each showing the relative reduction for obstacles in the directions between +/-90° horizontal and 0°-45° vertically. Each rectangular enclosure covers 30° horizontally and 5° vertically. For a particular overshadowing profile the percentages in each overshadowed area is summarized and the result gives the overall overshadowing effect (1-Fs).
This solar reduction factor Fs is in this investigation assumed to give a very good indication of the overshadowing effect on the efficiency of any proposed passive solar measure.
In order to exclude the impact of the camera position a specially developed made computer program for transforming the overshadowing data is used. The camera height above the ground, the distance to the facade and the height to the middle of the facade or roof is used for this correction.

The result indicates the overshadowing profile or data from a viewpoint at the center of facade or roof. The features of this transformation program are listed in appendix D.
For each solar facade and solar roof this correction have been made and the solar reduction factor Fs calculated. For solar facades in multi-storey buildings Fs have been calculated for each storey.

7. SIMPLIFIED REQUIREMENTS FOR PASSIVE SOLAR MEASURES

As mentioned before most of the passive solar measures are an integrated part of a building and its components. Every solution must therefore be individually adapted to each building. Consequently the cost and constraint of a particular solution will vary from building to building and so will the expected benefits. It is therefore very difficult to evaluate a particular solution on a neutral basis. In order however to treat the gathered material in a systematic way, it has been chosen to set up in a very simple way some preliminary topics of evaluations for the different passive solar measures :

Requirements	: Physical requirements and presence of conditions, which can invite to the use of this particular measurement.
Construction	: Problems regarding installation.
Other	: Occurrence of other constraint.
Investment	: Approximated cost of installation and maintenance.

Each suggested passive solar measure has been evaluated according to these topics using very simple terms.

7.1. MODIFIED WINDOW CONSTRUCTION

There is a great number of opportunities to choose from with this action. The cost and benefits can widely differ.

7.1.1. Adding an extra layer of glass to existing construction

Requirement :	-	One or two layers of glass in existing construction.
Construction:	-	Normally no problems. If an extra layer is installed on the inside, a proper sealing is necessary to avoid condensation problems.
Other :	-	Manageable. Can look appalling on especially older buildings.
Investment :	-	Small compared with other measures.

7.1.2 Replacement of old window construction with new sealed unit with selective coating and filled with a special gas.

Requirement :	-	One or two layers of glass in existing construction with no possibility of adding an extra layer of glass.
Construction:	-	Normally no problems.
Other :	-	Manageable. Replacement doubtful in older normal recidential houses from an esthetic point of view.
Investment :	-	Big.

7.1.3. Increase of southerly orientated window area

Requirements : - Total area of southerly, westerly and easterly orientated windows less than 10 % of total living area.
- Little overshadowing. Overshadowing of proposed placement is suggested to be :
  - < 10 % : Very good.
  - 10 - 20 % : Good.
  - 20 - 30 % : Doubtful.
  - > 30 % : Bad.
- Upper limit. The total area of southerly, westerly and easterly orientated windows greater then 20 % is not expected to increase the benefit further.
- Heat balance of windows better than the wall it should replace (see appendix E).
- Available useful facade area.
- Good heat capacity of building.

Construction : - Big problems, because the measure normally requires intervention of the structural function of the building.

Other : - Overheating, increased insight and architectural.
- The action is probably only recommendable in the case where the measure does not require intervention of the structural function of the building.

Investment : - Big.

7.1.4. Reduction of northerly orientated window area

Requirements : - Total area of northerly orientated windows greater than 10 % of floor area.

Construction : - No problems.

Other : - The measure will reduce natural light and in this connection the human comfort in the affected room.

- Windows are an important part of the fire escape routes in a normal Danish recidential house. There must be one escape route to the exterior form each room. Reduction of windows can only be done if the fire escape possibilities are still maintained.
- The measure is only recommendable in rooms which either have great window area or secondary functions.
- Much better solutions :
  - Movable insulation.
  - Translucent insulation.

Investment : - Medium

7.1.5. Reduction of window area in greatly overshadowed facades

Requirements : - Window area greater than 10 % of floor area (Danish Building Code).

- Heat balance of windows worse than a replacing wall (See appendix E).

Construction : - No problems.

Other : - Fire escape possibilities must be maintained.

- If a facade is greatly overshadowed the rooms behind it probably need all the light they can get to maintain a good human comfort.
- Probably only recommendable when adjoining rooms have a secondary function.
- Much better solutions :
  - Removal of obstacles causing the overshadowing (vegetation).
  - Increase of the heat resistance of the windows.
  - Movable insulation.
  - Translucent insulation.

Investment : - Medium.

7.1.6. Use of insulated window shutters

Requirements : Suitable window construction.

Construction : Difficult.

Other : - Only for dwellings. Requires manual control (daily in the winter time).

- Fire hazards must be solved. It must be possible to open both window and shutters from the inside.
- Esthetic constraint.
- Condensation problems with inside shutters. Must be tight, which is difficult to obtain. Inside shutters are not generally recommendable.

Investment : - Big.

7.2. ATTACHED SUNSPACES

Attached glass house or glass covering of balconies.

Requirements : - Southerly orientated facade (+/- 45°).
- Free area from facade :
  - 1 - 2 m : Small attached sunspace.
  - 2 - 5 m : Normal size.
  - > 5 m : Large.
- Overshadowing:
  - < 25 % : Good.
  - 25 - 35 % : Reduced benefits.
- Room behind:
  - Living room very applicable.
  - Sleeping/working room is less good.
- Big height of facade is an advantage as the slope of the glass roof must be greater than 25° to avoid snow problems.

Construction : - Existing door in facade is an advantage.

Other : - Legislative restrictions. Maximum built-up area. Fire escape must be possible. Overheating. Proper ventilation and sun shading of sunspace must be possible.
- Condensation. Avoid unheated rooms in connection with glass house.
- Secondary benefits :
  - Extended living area in greater parts of the year.
  - Building preservation. Protects old facade and windows.
  - Might be used instead of additional glass covering of windows.
  - Very usable as greenery.

Investment : - Medium.

7.3. SOLAR WALLS

General requirements :	-	Available area on southerly orientated facade.
	-	Orientation from south :
		0° - 30° Good
		30° - 45° Less good
	-	Overshadowing :
		< 20 % Good
		20 - 30 % Less good
		> 30 % Bad

7.3.1. Mass walls

Requirements :	-	Facades of concrete or brick.
	-	Uninsulated wall or wall with possibility of easy removal of existing insulation.
Construction :	-	Complicated.
Other :	-	Mass walls accumulate heat during the day and supply the adjoining room during the evening and night. This makes normal recidential houses the most adequate because they are used at this hour.
	-	Can be an alternative to additional insulation of an existing wall.
Investment :	-	Big.

7.3.2. Ventilated solar walls

Requirements : - Insulated wall of light construction.
- Large heat storage capacity of adjoining rooms or possibility of making separate heat storage.
- Not too big southerly orientated window area.

Construction : - Very difficult.

Other : - Automatic or manual regulations of ventilation louvers to prevent overheating and heat loss during night.
- Problems with dirt on absorber.

Investment : - Very big.

7.3.3 Trombé walls

Requirements : - Wall of concrete or brick.
- Uninsulated wall or wall with possibility of easy removal of existing insulation.

Construction : - Complicated.

Other : - The Trombé wall supplies the adjoining room during the day like the windows as well as accumulates heat for the night. The measure is therefore suitable for normal recidential houses with little southerly orientated window area.
- Problems with dirt on absorber.
- Can be an alternative to additional insulation of an existing wall.

Investment : - Big.

7.4. ROOF-SPACE COLLECTORS

Requirements	:	- Southerly orientated roof with tilt greater than 20°.
		- Unutilized roof space.
		- Airspace between insulation and roof covering.
Construction	:	- Complicated. Space for air ducts and heat storage must be possible.
Investment	:	- Big.

7.5. INCREASE OF HEAT STORAGE CAPACITY

Requirements	:	- Small thermal inertia of building.
		- Large westerly, southerly or easterly oriented window area.
Construction	:	- Complicated because additional concrete or brick walls or floors must be constructed and adapted to the existing construction of the house. Alternatively can e.g. phase change materials be used for heat storage.
Other	:	- In construction of Trombé or mass walls without using an existing facade, the concept of increasing the heat storage capacity is automatically involved.
Investment	:	- Strongly case dependent.

7.6. REDUCTION OF THE OVERSHADOWING EFFECT

Requirements : - Greatly overshadowed southerly oriented facades or roofs, which can be or are being used for passive or active solar measures. Suggestion; Solar reduction in the heating season (Oct.-Apr.) greater than 25 % and large existing window area or another proposed passive solar measure.

Construction : - Immediately it seems to be physical very easy to cut down trees and weed, but there will be problems with the concept of private property. It is unlikely to assume that neighbors will welcome this solution unless legislative measures are implicated.

Other : - Individual investigation of reduction possibilities in cooperation with inhabitants is necessary.
- Cutting down or pruning trees and weeds is likely to be the only realistic common procedure.
- Trees and weeds give shelter from the wind and thereby reduce the heat loss from the building. Cutting down or pruning of trees and weeds must therefore be done with great care not to obtain the wrong effect.

Investment : - Negligible.

7.7. ACTIVE SOLAR MEASURES

In order to compare the passive solar measures with other measures which might limit energy used for heating, the investigation has also to some extent implemented some active solar measures and the concept of additional insulation. This has only been done shallow.

General Requirements :	- Southerly orientated sloping roof	
	- Orientation :	
	0° - 30°	Good.
	30° - 45°	Less good.
	- Tilt :	
	30° - 45°	Good.
	45° - 60°	Very Good.
	60° - 70°	Good.
	- Overshadowing :	
	< 5%	Very Good
	5% - 15%	Good
	15% - 20%	Less good
	20% <	Bad
Construction :	- Possible placement on existing roof construction and roof covering.	
Other :	- Legislation. In some areas solar collectors on roofs are not allowed, because they are said to cause unacceptable sun reflections.	

7.7.1. Small domestic hot water systems

Requirements	: -	Normal recidential houses.
	-	Available room for smaller storage tank, water pipes and pumps etc.
Construction	: -	1-1.5 m^2 solar panel per inhabitant
	-	40-70 l storage tank per inhabitant
Investment	: -	Big.

7.7.2. Domestic hot water and space heating systems

Requirements	: -	Individual heating system.
	-	Available room for big storage tank, water pipes and pumps etc.
Construction	: -	Complicated
	-	5-10 m^2 solar panel per 1000 l oil used before.
	-	50-75 l storage tank per m^2 solar panel.
Investment	: -	Very big.

7.7.3. Large building block systems

Requirements : - Multi-storey buildings, row houses or houses in groups, in order to have short distances between collectors and storage tank.
- Room for very big storage tank, water pipes and pumps etc.
-

Construction : - Complicated.
- Solar panel area eq. to 5 % of the total living area.
- Short term storage :
  Storage capacity covering of 10-20 % of the total living volume.
- Annual storage :
  Storage capacity covering 1-2.5 times the total living volume.

Investment : - Very big.

7.8. POST-INSULATION

Requirements : - Uninsulated or poorly insulated construction.

Construction : - Unutilized roof space or hollow facade construction : Very easy.
Other : Fairly easy.

Investment : - Medium.

8. SELECTED SAMPLE

From the heat inspection archives a sample of buildings was selected approximately representing the relative number of households categorized by age and dwelling type.

Number of letters sent to owners : 103

Number of positive answers : 68

Number of investigated buildings : 67

(Impossible to regain contact with one owner)

Number of households in investigated buildings: 174

Fig 7 : Number of households investigated in the different categories and the corresponding correct number matching the statistic material (Fig 1. page 8)

Dwelling category	Year of construction			
	-1939	1940-59	1960-69	1970-79
Single family dwellings	9 (13)	11 (9)	6 (10)	8 (8)
Terraced and low rise, high density buildings	6 (3)	6 (7)	5 (3)	4 (6)
Multi-storey buildings	73 (64)	20 (24)	24 (16)	2 (12)

There have been some problems with categorizing the dwelling type. Some of the family dwellings have later on been defined as terraced buildings because they are inhabited by more than one family.

The selected sample can be considered as a fairly acceptable representation, when the small number of investigated buildings and dependency of positive owner replies are taken into account.

9. RESULT OF INVESTIGATION

In general the relevant data for an examination of the utilization of a specific passive solar measure is extracted from the main form according to the different requirements. The analyses have in some cases called for some personal estimations and assumptions due to insufficient information and individual character of buildings and suggested passive solar measures.

For all the buildings the annual heating requirement in the heating season has been calculated using a standard method for residential houses (Ref 7). For some passive solar measures the anticipated savings have been calculated using the same method. This method has required some assumptions which are listed in appendix F. The savings referred to in the following chapters are the savings of the heating requirement in the heating season (Oct.-April). For suggested measures which have a more complicated impact on a building e.g. attached sunspaces, solar walls, roof-space collectors and the active solar measures the savings are estimated in reference to other investigations.

9.1. GENERAL DATA ON SAMPLE

Sample :

Number of investigated buildings	:	67
Number of households in investigated buildings	:	174
Number of households owned	:	79
Number of households rented	:	95

Floor area :

Total living area (incl. basement and attic)	:	20758 m^2
Average living area per household	:	119 m^2
Heated basement area	:	4187 m^2
Heated attic area	:	1280 m^2
Commercial area	:	727 m^2

Heating :

Calculated average heat loss in the heating season per living area	:	130 kWh/m^2
Assumed average heat gain from persons and household in the heating season per living area	:	28 kWh/m^2
Calculated average heating requirement in the heating season per living area	:	102 kWh/m^2

Fig 8. Average heat loss distribution.

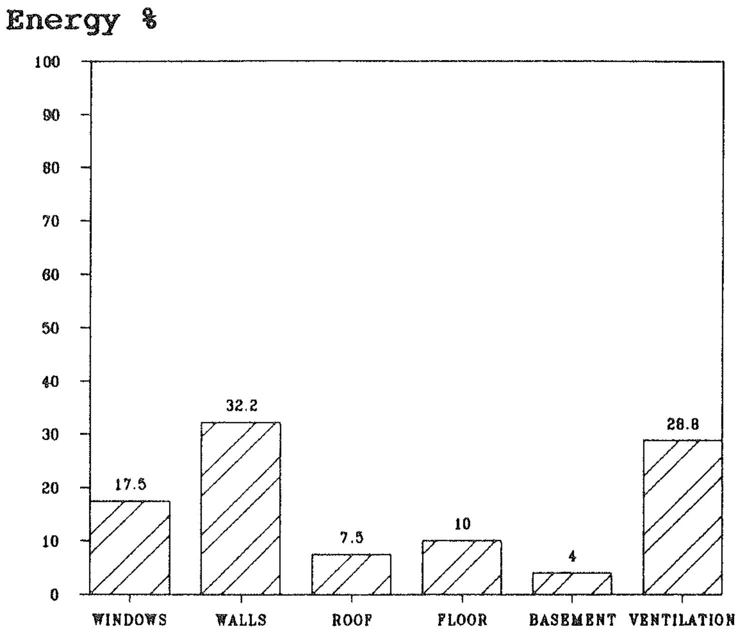
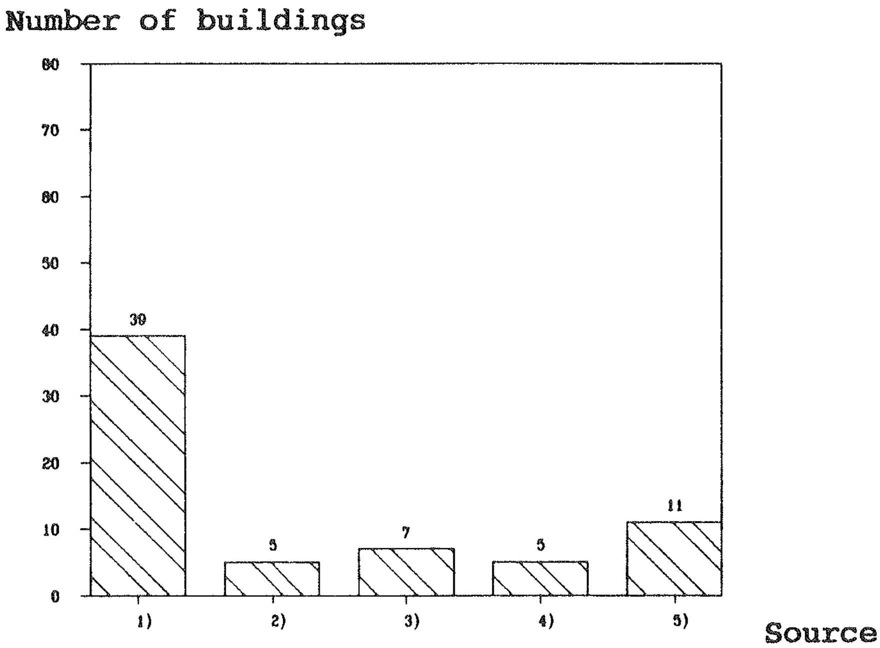


Fig 9. Primary heating source

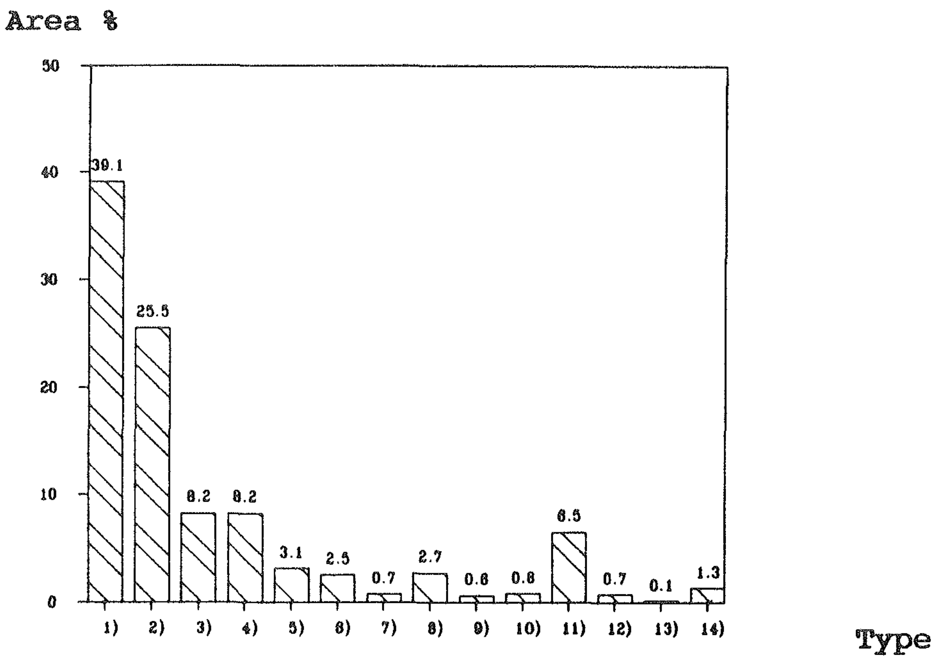


1) Fuel oil, central heating
2) Gas, central heating
3) District heating (coal and gas)
4) Kerosene
5) Electricity (coal and gas)

Facades :

Total facade area : 14475 m^2

Fig 10. Construction of facades



Facade type:

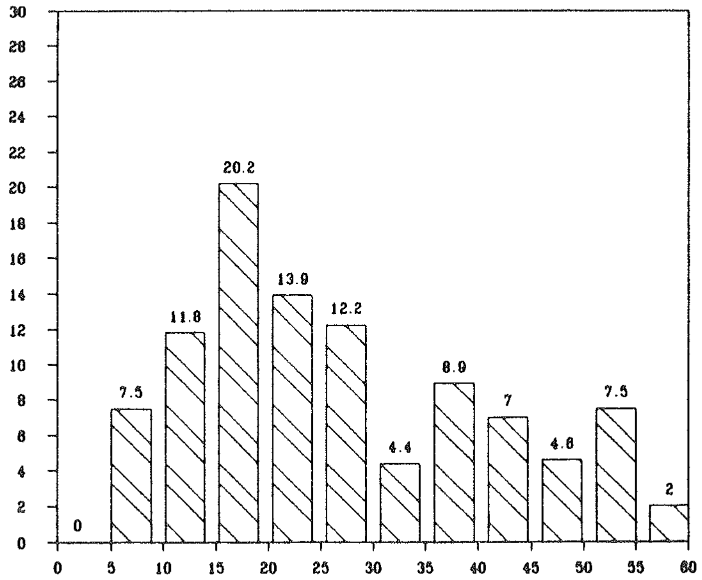
Outer leaf	Cavity	Inner leaf
1) Brick,	–	–
2) Brick,	Air	Brick
3) Brick,	Insulation	Aerated concrete
4) Brick,	Insulation	Brick
5) Brick,	Air	Aerated concrete
6) Brick,	Insulation	Board
7) Brick,	Aerated concrete	–
8) Aerated concrete,	–	–
9) Aerated concrete,	Insulation,	Board
10) Aerated concrete,	Air	Brick
11) Board,	Insulation	Board
12) Board,	Insulation	Aerated concrete
13) Board,	Air	Board
14) Half-timbering,	Insulation	Board

Information concerning facade type has only been recorded for solar facades. For the rest of the facades of a building the type is assumed to be the same. For buildings with no solar facades and consequently no recording of facade type the type is assumed to be type no. 2) or 3) depending on the age of the building.

Overshadowing of facades

Fig 11. Overshadowing of investigated solar facades

Area % (of total investigated solar facades).



(1-Fs)

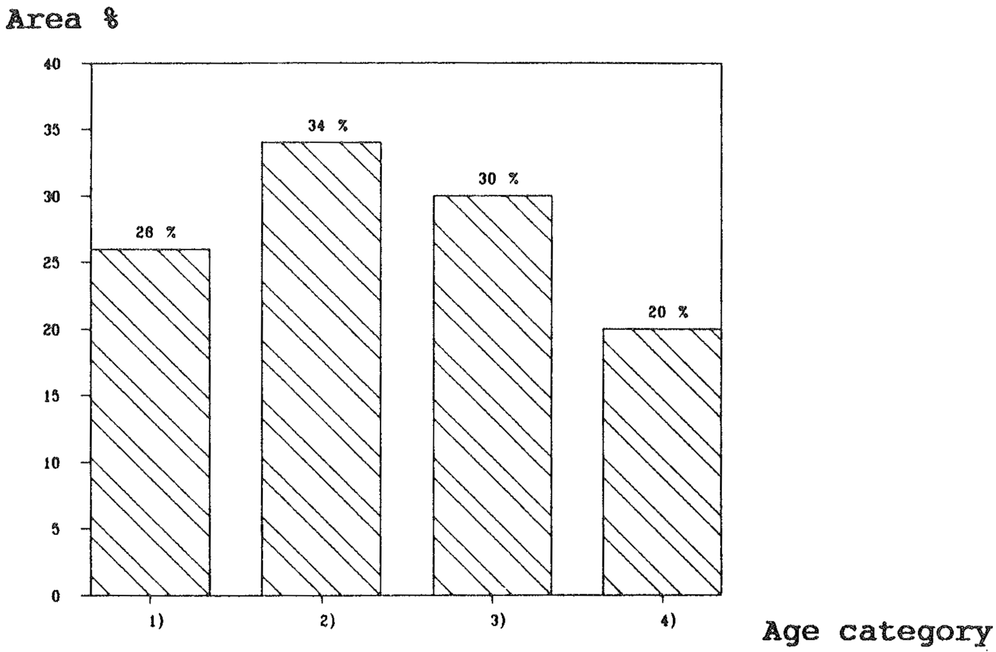
Objectives - Number of investigated facades : 72

Area of investigated facades : 3767 m²

Average (by area) overshadowing effect of facades : 28 %

Fs is the reduction factor for solar irradiation. Fig 11. shows that a great number of facades is very overshadowed. Almost 60 % of the investigated facades have overshadowing effect which can be described as less good or bad for application of passive solar measures.

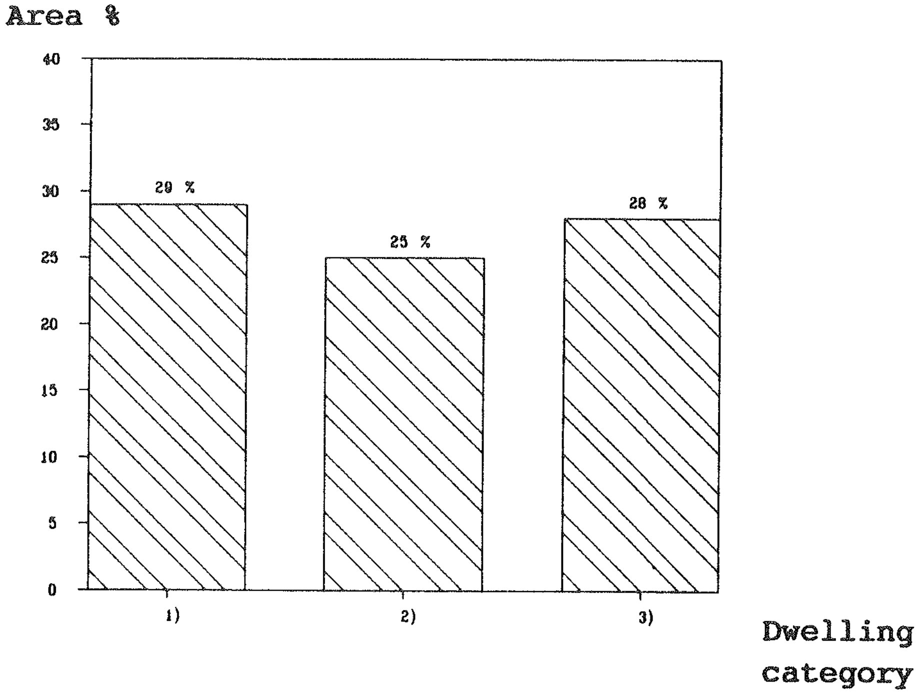
Fig 12. Average overshadowing effect for the facades of buildings in the different age categories.



1) - 1939
2) 1940 - 1959
3) 1960 - 1969
4) 1970 - 1979

Fig 12. indicates that facades of newer buildings in general are less overshadowed than facades of older buildings.

Fig 13. Average overshadowing effect for the facades of buildings in the different dwelling categories.



1) Single family dwellings.
2) Terraced and low rise, high density buildings.
3) Multi-storey buildings.

Fig 13 shows no significant dependency between the overshadowing effect and the dwelling type.

Windows :

Total window area : 2087 m^2

Total window area per total living area : 10.1 %

Fig 14. Distribution of orientation

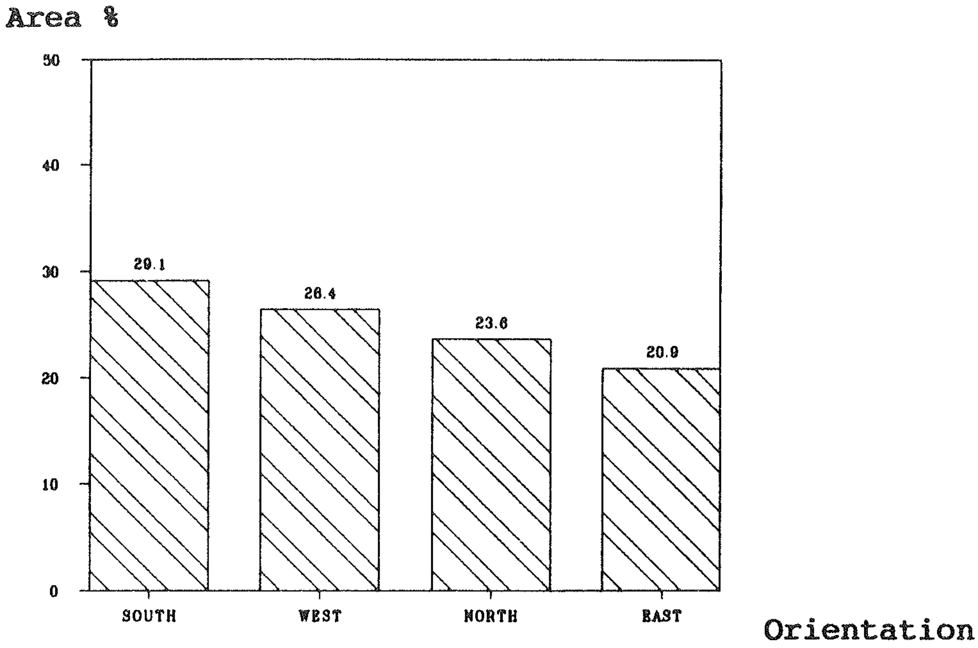
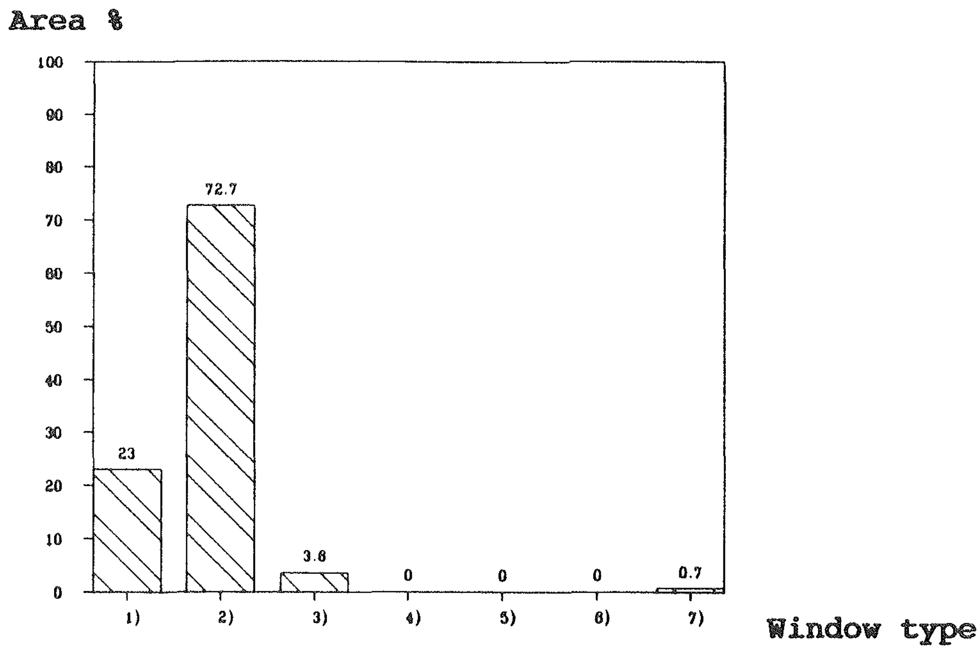


Fig 15. Window construction type



Window type :

1) One layer of glass.
2) 2 layers.
3) 3 layers.
4) 2 layers, coated.
5) 3 layers, coated.
6) 2 layers, one of them a storm window.
7) 3 layers, one of them a storm window.

Fig 16. Heat balance of windows in the heating season.

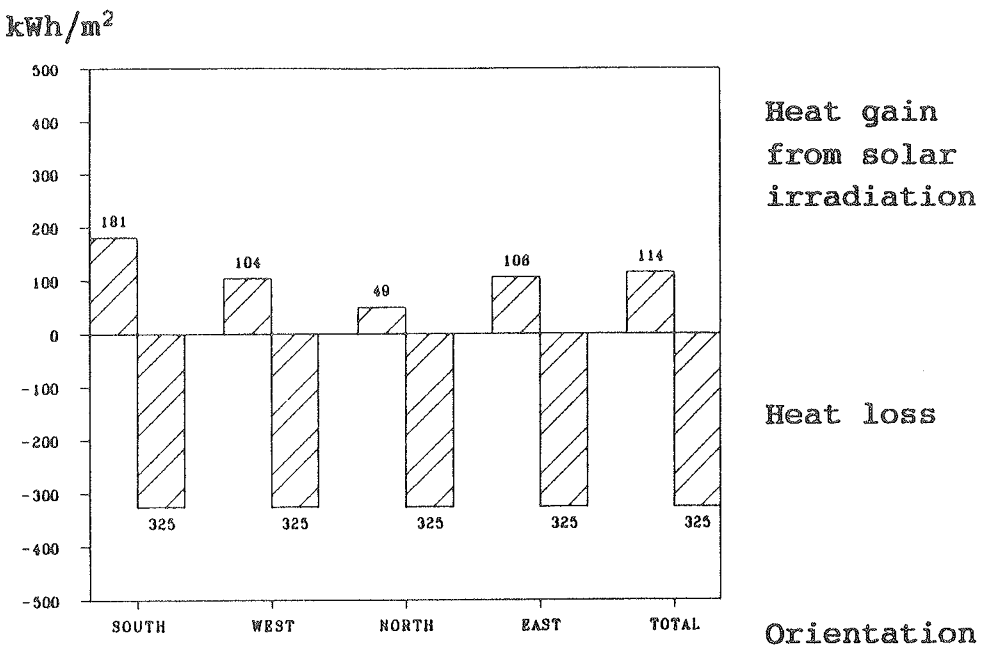


Fig 17. Heat balance for windows. Positive/Negative

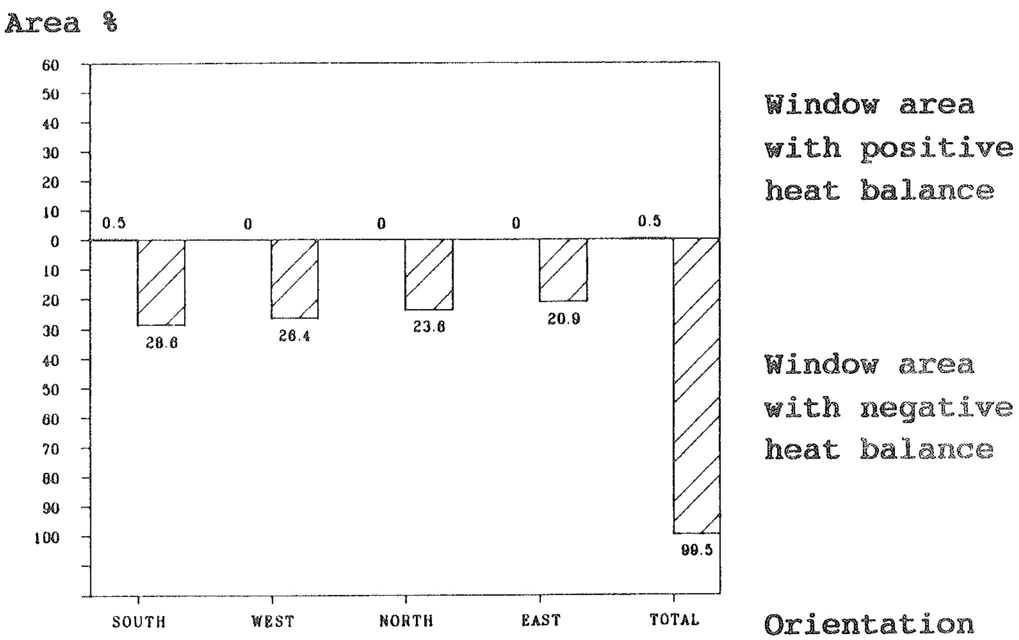


Fig 16. and 17. show that almost none of the investigated windows at the present have a positive heat balance i the heating season.

9.2. MODIFIED WINDOW CONSTRUCTION

There have been looked at six different measures.

9.2.1. Addition of an extra layer of glass to an existing one layer construction.

Objectives - All buildings with one layer of glass in the existing window construction.
Number of buildings found : 2
Area / total area of windows : 23 %

Investment - Little.

Benefits - Calculated to an average saving of 29 % per building involved, which is an overall saving of 6 %.

9.2.2. Addition of an extra layer of glass to existing one or two layer construction.

Objectives - All buildings with two layers of glass or less in the existing window construction.
Number of buildings found : 64
Area / total area of windows : 96 %

Investment - Little.

Benefits - Calculated to an average saving of 12 % per building involved, which is an overall saving of 11 %.

Economy - Medium. Case dependent.

Fig 18. Heat balance of all windows in the sample after addition of an extra layer of glass to 64 buildings.

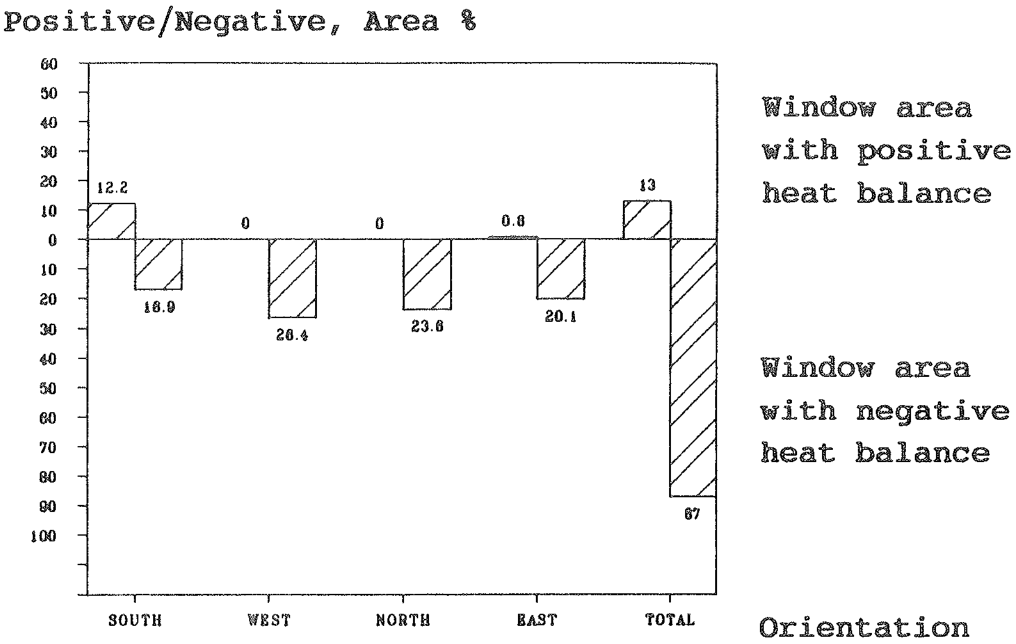


Fig 18. shows that the southern orientated window area with positive heat balance is increased from 0.5 to 12.2 %.

A hypothetical calculations have also been made to investigate the effect if all window of the investigated buildings where replaced of a three layer construction. This shows that a 14 % overall saving can be obtained.

9.2.3. Replacement of old window construction with new sealed unit with selective coating and filled with a special gas.

Objectives - All windows in the 67 buildings.

Investment - Very big.

Benefit - Calculated to an overall saving of 16 %.

Economy - Case dependent.

Comments - This is a purely hypothetical calculation to show the potential. It is not likely to assume that such a measure can be obtained. Other measures will probably come into question first. A total replacement will take many years, because the most economical procedure would be to replace an old construction which is thermally acceptable only when it is worn out.

9.2.4. Increase of southerly orientated window area

Objectives – Only one building in the selected sample has been found to have a positive heat balance of the southerly orientated windows. It has therefore been chosen to look upon an increase of southerly orientated windows in connection with a replacement of the old window construction to a new sealed unit with selective coating and filled with gas. A visual evaluation of photos and deposited plans has been used as the basis of a possible application of this measure.

Number of building found adequate :	23
Window area / total southerly window area :	24 %
Increase of window area :	10-100 %
Average increase of window area :	12 %

Investment – Very big. In nearly all the buildings the measure would require intervention of the structural function of the building.

Benefit – An average saving of 9 % of the buildings involved has been calculated. This is a 2 % overall saving. Of this one half is due to replacement of the window construction and the other half due to increase of window area.

Fig 19. Heat balance of all windows in the sample after increased area and changed construction of 23 buildings.

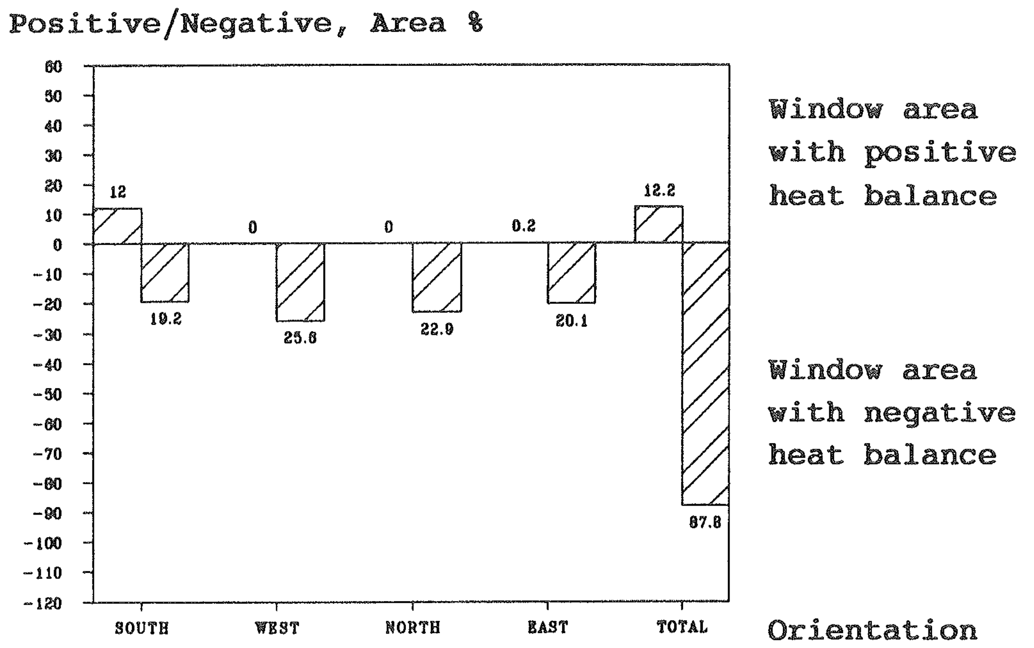


Fig 19. shows that the total area of the windows with a positive heat balance is increased from 0.5 to 12.2 % when 23 buildings have increased southerly area together with changed construction.

Economy - It seems that this measure is not economical feasible in any of the investigated buildings as the investment will be very big. It will only be recommended in cases where the increase of the window area does not require intervention of the structural function of the building.

9.2.5. Reduction of northerly orientated window area

Objectives - By careful study of deposited plans a reduction of the northerly orientated window is only possible for very few buildings.

Benefit - Calculated savings have been found to be negligible.

9.2.6. Reduction of window area in greatly overshadowed facades.

Objectives - Number of investigated facades : 72

Area of investigated facades : 3767 m^2

Fig 11. page 36 shows that a great number of facades is greatly overshadowed. But in defiance of this, examples of possible reduction of the window area have been very hard to find. In the few cases where it might be possible other solutions such as improved window construction seem more suitable.

The consequence is that no facades have been found where a reduction of the window area is suggested.

9.2.7. Use of insulated window shutters

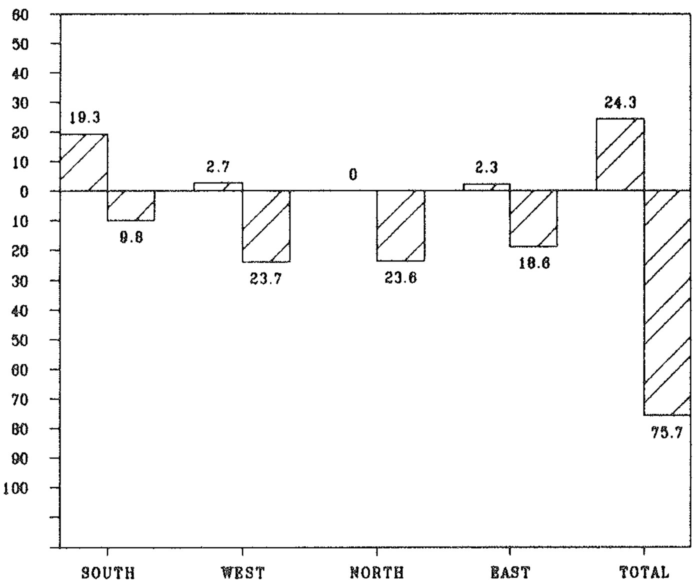
Objectives - Number of buildings found suitable for installation of insulated shutters : 52

Area of windows potential for installation / total window area : 48 %

Benefits - If shutters with 10 cm insulation are installed and used in the night time an average saving of 12 % is calculated for the buildings involved. This is an overall saving of 6 %.

Fig 20. Heat balance of all windows in sample after installation of insulated shutters to 52 building.

Positive/Negative, Area %.



Window area with positive heat balance

Window area with negative heat balance

Orientation

Fig 20 shows that the total area of windows with positive heat balance is increased from 0.5 to 24.3 % by using insulated shutters on 52 buildings.

9.3. ATTACHED SUNSPACES

Objectives :

Number of southerly oriented facades : 85

Total area of southerly orientated facades: 3736 m^2

Numbers of facades found possible for application of attached sunspaces : 39

(Of these 16 have reduced benefits due to great overshadowing).

Area of facades found possible for application of attached sunspaces / total area of southerly orientated facades : 39 %

Numbers of facades found possible for application of attached sunspaces on balconies : 4

Area of facades found possible for application of attached sunspaces on balconies / total area of southerly orientated facades: 4 %

Benefits :

According to the case study page 69 and Ref 9 the relative savings obtained in the heating season are expected to be very small :

Small sunspace : 0-2 %

Large sunspace : 1-3 %

Very large sunspace : 2-4 %

Restraint for application of attached sunspaces :

Number of facades not usable for application of attached sunspaces :	42
Area of facades not usable for application of attached sunspaces :	2376

Reason :		Number :	Area :	Rel. :
1)	No space	23	1069	68 %
2)	Too great overshadowing	21	942	60 %
3)	Architectural	4	100	6 %
4)	Already existence of sunspace	1	30	2 %

Some of the facades have more than one reason for not being usable for application of attached sunspace.

9.4. SOLAR WALLS

General information :

Total number of investigated walls :	72
Total area (without window area) of investigated walls :	3040 m^2

9.4.1. Mass walls and Trombé walls

Objectives - Number of facades with solid walls found possible for application of Mass or Trombe walls : 11

Area / total investigated area : 18 %

Area / total southerly area : 14 %

Of this 5 of the walls will have somewhat reduced benefits due to overshadowing and orientation.
For most of the facades application is complicated by the windows in the facade. It seems that the multi-story buildings have the largest continuous area for possible use.
Another type of wall which might be suitable for Mass and Trombe walls is the cavity wall. This will require a relatively larger investment for filling up the air space between the inner and outer leaf with solid material.

Number of possible cavity walls found : 17

Area of possible cavity walls found / total area investigated : 13 %

Area / total southerly area : 10 %

Of this 8 of the walls will have somewhat reduced benefits due to overshadowing and orientation.

Benefits - The benefits will be strongly case dependent. According to Ref 9 the relative savings in the heating season is expected to be approximately 100 kWh/m^2 wall. For the walls investigated this is an average saving around 5-10 % of the requirement for heating.

Economy - With exception of a few facades most of the facades have to little area and too many constructional problems mostly due to window placing that the investment probably will be unsound.

9.4.2. Ventilated solar walls

Objectives - As the ventilated solar walls requires a light wall construction and this type mostly has been used in newer houses only very few facades have been found suitable for application of ventilated solar walls.

Number of facades found suitable : 5

Area / total investigated area : 2 %

Area / total southerly area : 2 %

Of these facades two will have reduced benefits due to overshadowing on orientation.

Benefits - Strongly case dependent.

Economy - The areas of the facades found seems a bit more regular than the areas found suitable for application of Mass and Trombe walls, but it is difficult to predict the economical feasibility of an application of ventilated solar walls on the buildings found.

9.5. ROOF-SPACE COLLECTORS

Objectives -	Number of investigated roofs :	57
	Area of investigated roofs :	2820 m^2
	Number of roofs found suitable for installation of roof-space collectors :	20
	Area of roofs found possible for installation of roof-space collectors :	920 m^2

Investment - Strongly case dependent. Big.

Benefits - Case dependent. Medium. Of the 20 roofs found suitable 8 will have reduced benefits due to orientation.

Economy - Strongly case dependent.

Restraint -	Number of roofs not found suitable for installation of roof-space collectors :	37
	Area of roofs not found suitable for installation of roof-space collectors :	1900 m^2

Reason :		Number :	Area :	Rel. :
1)	Flat roof	6	501 m^2	26 %
2)	Too little room	10	436 m^2	23 %
3)	Utilized roof-space	19	885 m^2	47 %
4)	Too great overshadowing	7	231 m^2	12 %

Some of the roofs have more than one reason for not being suitable for installation of roof-space collectors.

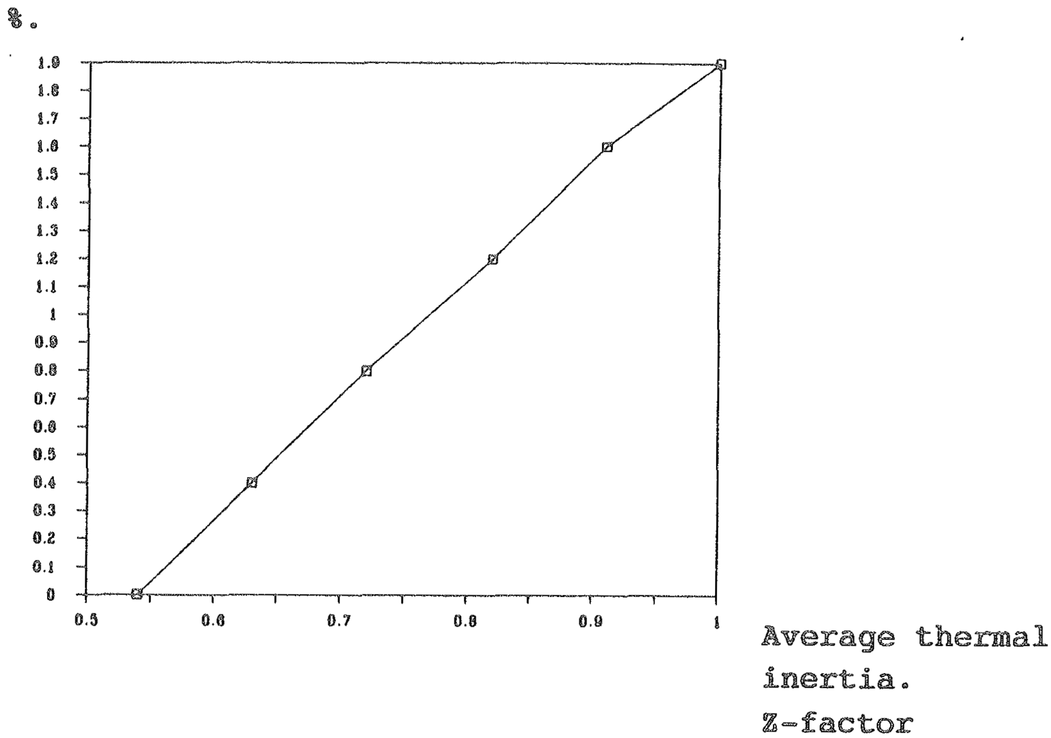
9.5. INCREASE OF HEAT STORAGE CAPACITY

Objectives - Due to lack of specific information regarding the interior of the investigated buildings it has been very difficult to propose an increase of the heat storage capacity for a particular building. However the thermal inertia described relatively with one simple factor Z (0.0-1.0, 0,0 is a very light building, 1.0 is a very heavy building) for the total building has been estimated using deposited plans and photos. Hypothetical calculations have been made where this factor is increased for all the investigated buildings regardless of the individual building's construction. This is only done to enlighten an eventual potential for savings which might be obtained by a general increase of the thermal inertia of the building stock.

Number of buildings involved :	67
Average (by living area) thermal inertia Z :	0.54

Benefits - The inertia for each building has been gradually increased from the registered present value to the maximum (Z=1.0). The result is presented in Fig 21.

Fig 21. Savings obtained by increase of the general thermal inertia of all the investigated buildings.



The calculations show that an increase of the thermal inertia as the only measure implemented does not have a very large effect on the heating requirement, but it is assumed that a large thermal inertia of a building is crucial for a number of other passive solar measures.

9.7. REDUCTION OF THE OVERSHADOWING EFFECT

Objectives	-	In order to establish the potential for reduction of overshadowing obstacles all 72 investigated facades have been visual examined to see the effect if all trees and weeds were cut. This reduces the average overshadowing effect from 28 % to 19 %. Calculations show that this measure only resulting a 1.4 % overall saving. A very little effect. A more realistic calculation has been made. Here only more realistic reductions assumed by imaginative pruning and reduction of weeds in the garden belonging to the building in question.	
		Number of facades where a realistic reduction is possible :	27
		Average overshadowing of the facades involved after the reduction :	22 %
Benefits	-	Overall savings obtained :	0.3 %
		Average saving for the buildings involved :	0.7 %
Economy	-	As the investment is negligible the economy of this measure probably is good. But the effect is very little.	

9.8. ACTIVE SOLAR MEASURES

General information :

Objectives -

Number of investigated roofs :	57
Area of investigated roofs :	2820 m^2
Number of roofs found suitable for installation of active solar measures when the requirements of orientation, overshadowing and tilt of roof are obtained :	21
Area :	1076 m^2
Number of roofs not found suitable for installation :	36
Area of roofs not found suitable for installation :	1744

Reason :	Number :	Area :	Rel. :
1) Flat roof	6	501 m^2	29 %
2) Tilt angle less than 30^0	24	1050 m^2	60 %
3) Too great overshadowing	7	231 m^2	13 %

Some of the roofs have more than one reason for not being suitable for installation of active solar measures.

Of the remaining 21 roofs additional 4 were found to be less suitable due to inadequate roofing (straw), architectural and legislative reasons.

Remaining roofs found suitable for installation of active solar measures :	18
Remaining area found suitable for installation of active solar measures :	861 m^2
Possible area / investigated area:	31 %

9.8.1. Small domestic hot water systems

Objectives -	Number of roofs found suitable for installation of small domestic hot water systems :	13
	Area of roofs found suitable for installation of small domestic hot water systems :	685 m^2

Benefits - Assumed to 100 % of hot water supply in the summer for the buildings involved.
65 % of the hot water supply a year for the buildings involved.
Of the 13 buildings two will have reduced benefits due to orientation.

9.8.2. Domestic hot water and space heating systems

Objectives - Number of roofs found suitable for installation of domestic hot water and space heating systems : 7

Area of roofs found suitable for installation of domestic hot water and space heating systems : 576 m^2

Benefits - 25-30 % of total energy used a year.

9.8.3. Large building block systems

Objectives - Number of roofs found suitable for installation of large building block systems : 4

Area of roofs found suitable for installation of large building block systems : 176 m^2

Benefits - With no storage :
5 % of annual heating requirement.

With short term storage :
10-15 % of annual heating requirement.

With seasonal storage :
40-80 % of annual heating requirement.

Of the 4 buildings one will have reduced benefits due to orientation.

Economy - Strongly case dependent.

9.9. POST INSULATION

Two measures and a combination of the two have been investigated.

9.9.1. Post-insulation of cavity wall constructions using granulated insulation material

Objectives -	Fig 10. page 35 shows that approximately 30 % of the facade walls are constructed with a solid outer leaf, an air gap and a solid inner leaf. This is a very great potential. The area might be somewhat overestimated due to lack of information. It has not always been possible to confirm if the measure had already been applied.
Investment -	Little.
Benefits -	An average saving of 19 % and an 8 % overall saving have been calculated.
Economy -	If savings of this size can be obtained the economy of this measure is very good.

9.9.2. Post insulation of solid facade walls.

Comments - Suggested 10 cm outside or inside additional layer of insulation on all solid facades.

Objectives - Facade construction, which only have one solid layer (brick). According to Fig 10 page 35 there is a great potential of 41 % of the total facade area.

Benefits - Calculated to an average saving of 34 % of the buildings involved. This is an 16 % overall saving.

Investment - Big.

Economy - All the involved buildings seems to have a high saving percentage and no constraint has been found in any of the building, which could prevent an application of this measure. In some cases the measure requires a slight reduction of the living area or a changed appearance of the outside of the building.

9.9.3. Post-insulation of all poorly insulated facades

Post-insulation of both cavity and solid walls.

Objectives - Approximately 71 % of the total facade area. A great potential is found in older apartment buildings with rented flats.

Benefits - Overall saving calculated to 27 %.

Economy - Post-insulation of poorly insulated walls is a well proven procedure and a lot of private companies have performed this work in the last 10-15 years. As the economy is good, it would be advisable to make an emphasis to pursue this task for the remaining buildings.

12. COMBINED SCHEME

In order to estimate the overall potential for application of passive solar measures each of the buildings have been investigated for for application of a combination of the most economically feasible measures. These are :

1) Changed window construction.
   Existing one layer windows changed to two layers.
2) Use of insulated shutters.
   10 cm insulated shutters used in the night time with manual control.
3) Reduction of the overshadowing effect. (Expected savings are very small but so is the investment).
4) Post insulation.
   All possible insulation of cavity walls and inside or outside insulation of solid walls. 10 cm insulation of brick and concrete walls and 5 cm insulation of aerated concrete walls.
5) Attached sunspaces.
   - S : Small.
   - L : Large.
   - VL: Very large.
   - B : Glass covering of balconies.

   (The savings obtained are expected to be very small but the measure has secondary such as increased living area).
6) Mass or Trombé walls.
7) Ventilated solar walls.
8) Roof-space collectors.

The result is a proposed action for each building showed in Fig 22. The relative savings of the heating requirement in the heating season (Oct.-April) have been calculated for the impact of changed window construction, use of insulated shutters, reduction of the overshadowing effect and the effect of post insulation. For the other measures: Attached sunspaces, the solar walls and the roof-space collectors the expected savings are estimated accordingly to the case studies and the References.

Fig 22. Suggested passive solar measures for the buildings investigated.

Survey number	Changed window construction 1)	Use of insulated shutters 2)	Reduction of the overshadowing effect 3)	Post insulation 4)	Attached sunspace 5)	Mass or Trombe wall 6)	Ventilated solar wall 7)	Roof-space collector 8)	Total savings %
S097		x	x	x		x		x	56
S096		x	x	x	S				29
S089		x	x	x	S			x	53
S135			x	x	VL				52
S093		x		x	B			x	53
S100		x		x					38
S047		x	x					x	29
S132					S				1
S039		x	x	x	L				16
S048		x	x	x		x			46
S027		x					x		24
S082		x		x				x	48
S115		x		x					46
S087		x		x					48
S113		x		x					41
S126				x					40
S125		x		x					34
S109		x		x	S			x	53
S053		x	x	x	L			x	37
S108		x	x		S				9
S010		x		x				x	48
S019		x	x	x					37

Continued on the next page.

Survey number	Changed window construction 1)	Use of insulated shutters 2)	Reduction of the overshadowing effect 3)	Post insulation 4)	Attached sunspace 5)	Mass or Trombe wall 6)	Ventilated solar wall 7)	Roof-space collector 8)	Total savings %
S023		x	x	x	S				36
S054		x	x		L				18
S058		x			S				16
S105		x			L				14
S129		x	x		L				7
S095		x	x		S			x	48
S030		x	x	x	L				18
S098		x	x		B			x	25
S122				x		x			40
S018		x		x	L				15
S080		x			L			x	26
S088		x		x	L			x	40
S012		x		x	S				33
S061		x	x	x					36
S102		x	x		S				14
S014		x			L				7
S015		x	x	x		x			30
S050		x	x					x	26
S104		x		x	S			x	43
S075		x	x	x			x		36
S044		x		x					35
S001		x		x					39
S040		x	x		S				11
S045		x			L				19
S029			x		B				2
S028			x		B				1
S103		x	x	x				x	44
S026		x			S			x	20
S072		x	x	x	S				16
S051		x			L				18
S037		x		x	S				39
S055		x							10
S056		x			S				21
S074				x		x			30
S120				x					34
S139				x	L			x	47
S144				x					36
S142				x					29
S118				x					35
S117	x			x	S				52
S112		x		x	L				20
S060		x	x		VL			x	21
S136				x					27
S138	x			x	S			x	62
S092		x		x					42

Comments :

The small number of buildings found suitable for application of solar walls is due to the fact that it has been difficult to find large continuous possible areas. In some cases attached sunspaces have been found more feasible. In the case of the ventilated solar walls very few light facades were found.
Some of the proposed solar walls and attached sunspaces have reduced benefits due to overshadowing.
The great number of suggested insulated shutters is probably not realistic to expect in reality. The physical and economical requirements seems to be present, but as the measure requires participation of the inhabitants for daily use and as it changes the appearance of the buildings radically it is likely to assume that this measure will be applied to only a moderate number of existing buildings .

Result :

The overall relative saving obtained through the proposed scheme have been found to be 39 % of the heating requirement in the heating season. This is obtained by :

1)	Changed window construction :	6 %
2)	Use of insulated shutters :	5 %
3)	Reduction of the overshadowing effect :	0 %
4)	Post insulation :	24 %
5)	Attached sunspaces :	1 %
6)	Solar walls :	1 %
7)	Roof-space collectors :	2 %

This result should be treated with care as :

- The sample is relatively small.
- The calculations made are only based on data extracted from the photos taken and the described survey questionnaire.
- Missing information of some buildings has been estimated according to the rest of the sample or general assumptions. This especially concerns buildings, where no solar facades have been investigated, and consequently no information about wall type etc. has been recorded.
- For some of the suggested passive solar features calculations of the heating requirement are based on the use of a simple method. For the more complex measures in terms of thermal effect the savings are estimated according to other investigations together with the estimated size of the effect of the measure for each building.
- The combined scheme is a result of the evaluated feasibilities of the proposed features. But due to the complex nature of the gathered material and the definition of the simplified requirements for each measure, the result is bound to be influenced by somewhat personal evaluations.

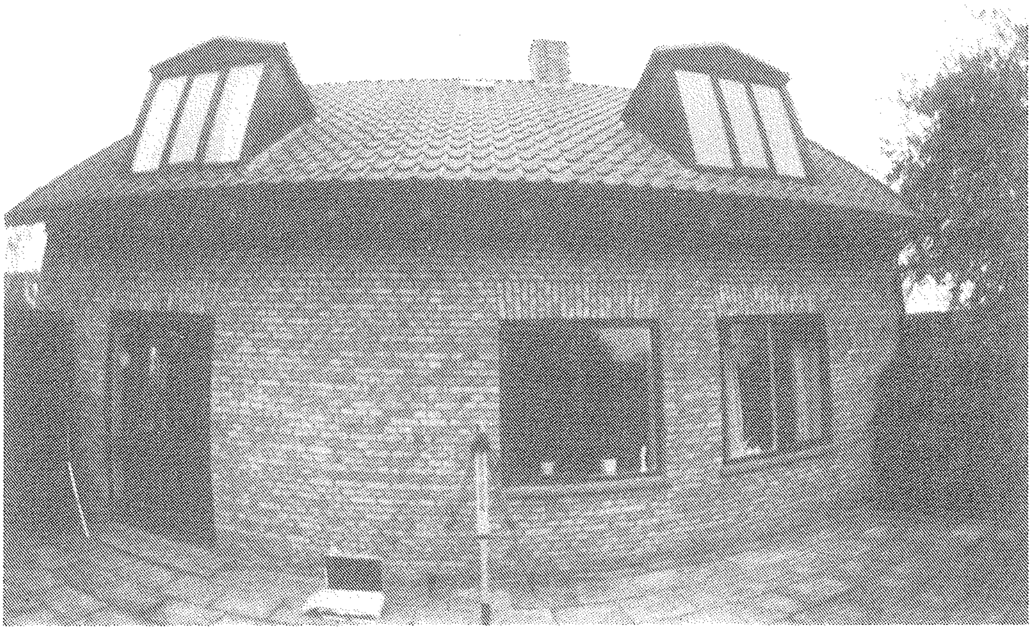
Bearing this in mind the result should only be used as indications of some main features of the potential for application of passive solar measures in the existing building stock.

13. CASE STUDY

A more detailed study has been carried out on building no. S105. This has been done in order to validate the prior mentioned simple method for determination of the heating requirement and to investigate the use of more complicated (in terms of calculations) features . The house is inhabited by two families. The collected data is listed in appendix B.

Living area :		151 m^2
Basement area :		85 m^2
Souther facade area :		28.4 m^2
Wall type :		Brick,Insu,Brick
Wall thickness :		11, 8, 11 cm
South window area :	Glass :	5.6 m^2
	Frame :	2.0 m^2
Glazing, number of layers :		2
Overshadowing of the facade :		30 %

Fig 23. Picture of south facade of building no. S105.



Possible measures :

1) Use of insulated shutters. 10 cm insulated shutters on all windows in the building except on dormer windows on the first floor. Used in the heating season from approximately 10 pm to 6 am.

2) To lower the indoor temperature requirement from 20^0 C to 16^0 C in the night time from 10 pm to 6 am.

3) Large attached sunspace covering half of the facade. Area : 16.8 m^2

4) Very large attached sunspace covering the whole facade. Area : 33.6 m^2

The area is an additional living area most of the year.

5) Both use of insulated shutters and very large attached sunspace.

Calculations with the program SUNCODE in the heating season:

Heating requirement of the existing construction : 19900 kWh

Savings with the proposed measures :

1)	2)	3)	4)	5)
9 %	10 %	1 %	3 %	10 %

The savings obtained by the use of insulated shutters were prior calculated with the use of the simple method to 12 %, but in this calculation was also included insulated shutters on dormer windows on the first floor.

12. DISCUSSION OF METHOD AND SUGGESTED CHANGES IN PROCEDURE

The experience of completing the whole investigation has let to some proposals for a changed procedure which can be useful in similar investigations.

- In order to have a better overall basis of information on the selected sample, the extent of the collected data should be the same for all the investigated buildings and so detailed that it enables an easy calculation of the heating requirement. This basis is useful for making a better material to relate the possible passive solar features to. It is suggested to obtain information on wall and window construction for all facades, regardless of their orientation and early stage evaluation of possibilities of application of passive solar measures. As it is now too many unnecessary assumptions had to be made. Furthermore it would be recommendable to record areas for each facade, and to obtain additional information regarding wall insulation and percentage frame area in window construction. Information on floor and basement construction could also be advantageous to obtain.

- Standard forms. It is proposed to divide the main form into parts which match the information sources so the appearance is more systematic :

1) A part for general information; Address, owner etc. (Page 7 in the existing main form, App. A).
2) A part for information gathered from the deposited plans regarding geometry and construction (Page 1 to 5 in the existing main form).
3) A part containing information gathered at the on-site investigation. Window construction, the photo data and the result of the photo transformation (page 9 in the existing main form). The data in the photo form can be incorporated in the main form.

- Regarding the photographic method. The used 16 mm fish-eye lens was originally selected for the purpose of only taking two pictures to cover a 180° profile horizontally. As this not could be achieved the camera arrangement should be changed using another lens. It is advisable not to trust sale specifications, but to test the lens before making the final camera set-up.

- Analysis of collected data. In defining characteristics in the vast number of collected data have arisen some complications. The various different values make it difficult to define characteristics useful for sensitivity studies. It is advisable to make these definitions at a very early stage. This involves a discussion as to which extent computers should be used in the evaluation of data.

13. CONCLUSION

A sample of 67 buildings (174 households) representing the Danish building stock quite well has been investigated. Information regarding geometry and construction has been recorded and the overshadowing effect of facades and roofs possible for application of passive solar measures investigated. The data has been analyzed statistically to find general features for application of passive solar measures in the existing building stock in Denmark.

The described investigation method has proved to be very efficient. Especially the use of standard forms implemented on computer and the photographic method to determine the overshadowing effect of a facade or a roof have exceeded the expectations. However the definitions of concepts and development of the different procedures have been somewhat too time consuming.
In the analysis of the large number of collected data too many exceptions and individual characters of the different buildings have been difficult to treat in standard forms. This has slowed down the handling of data and consequently the expected number of investigated buildings has not quite been reached. Smaller changes in the forms for data collection are recommended.

As the sample is rather small and the analysis of the collected data has required some estimations, the derived results should only be used to indicate some main features of the potential for application of the passive solar measures in the existing building stock :

- The general potential for application of passive solar features seems very little.

- The general overshadowing effect on facades is very big, but does vary a lot. General reductions of the overshadowing do not seem to be realistic, and the effect would be very little. The efficiency of other proposed measures are on the other hand believed to be very much depending on the overshadowing.

- The potential for application of solar walls is very small and application of this measure is constrained by too little continuous areas available and overshadowing.

- Possible areas for installation of roof-space collectors seems present, but the feasibility of the use has to be investigated further. The advantages of roof-space collectors will in many cases be evaluated together with a possible use of active solar measures.

- A relatively large number of the investigated buildings can be applied sunspaces, although the savings obtained are not expected to be very big.

- Indicated by this investigation there is a great potential for use of insulated shutters. But as this measure have some esthetic restraint and human requirements, it must be a question how realistic this possibility is. Furthermore installation of insulated shutters requires a more detailed investigation than performed here for examination of especially the technical possibilities for attachment of the shutters.

- Increase of the thermal inertia is considered very laborious and the effect of making this feature alone seems negligible. In connection with other measures the thermal inertia is likely to be very important.

- Only a few buildings have been found suitable for reduction of the northerly orientated windows. The savings are found to be negligible.

- The big investment in connection with increase of southerly oriented windows makes this measure very economically unsound.

- The major possible savings found are obtained by post insulation of poorly insulated facades, which still seems to have a great potential in the existing building stock.

- The potential savings obtained by adding an extra layer of glass on one layer window constructions are (of cause) relatively large.

- As the economy for post-insulation and the concept of improving one layer window constructions is good, it would be advisable to make an emphasis to pursue these tasks through legislation or other incentives.

It is possible to analyze the collected data further and more conclusions can probably be derived. The material is expected to be useful in other project in the future.

14. REFERENCES

1) "European passive solar handbook", Edited by P.Achard and R.Gicquel,Commission of the European Communities, Directorate-General XII for Science, Research and Development, Solar Energy Division 1986.

2) "Passiv solvarme - Projekteringsvejledning", Teknologisk Institut-Varmeteknik, Laboratoriet for Varmeisolering-DtH, Energiministeriets Solvarmeprogram-Rapport nr. 30, ISBN 87-7511-565-4, 1985.

3) "Energi- og boligforbrug i forskellige husstande", SBI-rapport 195, Statens Byggeforskningsinstitut, ISBN 87-563-0698-9, SBI, Horsholm 1988.

4) "Passive Solar Heating in Existing Dwellings", F.Penz and D.Hawkes, The Martin Center for Architectural and Urban Studies, University of Cambridge Department of Architecture 1983.

5) "Passive Solar Housing in the UK", D.Turrent, J.Doggart, R.Ferraro, The Energy Technology Support Unit, Harwell 1980.

6) "Sollys og Dagslys-maalt og beregnet", E. Petersen, Lysteknisk Laboratorium, DtH 1982.

7) "Beregning af energiforbrug i smaahuse", SBI-rapport 148, Statens Byggeforskningsinstitut, ISBN 87-563-0538-9, Glostrup 1984.

8) "Beregning af bygningers varmetab", DS 418, Dansk Ingeniorforening, Normstyrelsen, NP-138-S, ISBN 87-571-0547-2, Teknisk Forlag, Kobenhavn 1986.

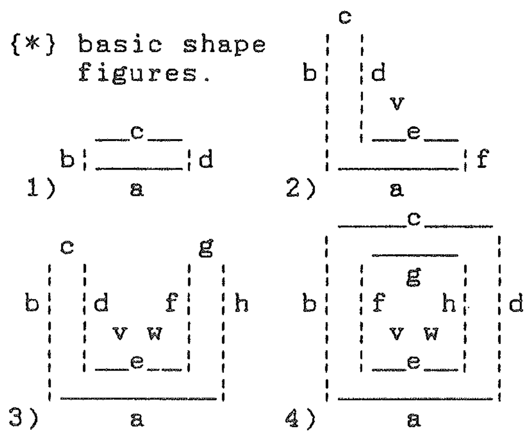
9) "Solvaegge i den eksisterende boligmasse", Casper Paludan-Muller, Olaf Bruun Jorgensen, Energiministeriets solenergiforskningsprogram, Rapport nr 47, DtH 1988.

15. APPENDICES (A -F)

APPENDIX A : MAIN SURVEY QUESTIONNAIRE

SAMPLE NUMBER >105< (floor plan) Page 1 out of 9 pages.

1	=> BASIC_SHAPE code (see {*} below)	BASIC_SHAPE code	>1<	1-4
2	=> ORIENTATION_ANGEL q {*} between the normal to the facade 'a' and true south. 0-360 deg, clockwise, starting in south.	ORIENT.ANGEL q	> 3<	deg 0-360
3	=> BLOCK_ANGEL.V (see {*})	BLOCK ANGEL V	>- <	deg
4	=> -~- .W	W	>- <	deg
	(=> '-' if angel do not exist)			0-180
5	=> FACADE_LENGTH[a..h]	LENGTH a	> 10.6<	m
6	=> {*} basic shape figures.	b	> 8 <	m
7	=>	c	> 10.6<	m
8	=>	d	> 8 <	m
9	=>	e	>- <	m
10	=>	f	>- <	m
11	=>	g	>- <	m
12	=>	h	>- <	m
	(=> '-' if facade do not exist)			
13	=> PROJECTIONS to facade a-h	PROJECTIONS facade	>- <	a-h
	(=> '-' if no neighbours)			max 4
14	=> BASEMENT type - = No basement. 1 = Partly basement. 2 = Full basement. 3 = Crawl space.	BASEMENT type	>2<	0-3



SAMPLE NUMBER _ _ _. (floor plan) Page 2 out of 9 pages.

15	=> SOLARFACADE1.PLACING	SOLARFACADE1 placing	>a<	a-h
16	=> -~- .DESCRIPTION	description	>18<	1-9
17	=> -~- .ROOMS_BEHIND	rooms behind	>lr <	code
18	=> SOLARFACADE2.PLACING	SOLARFACADE2 placing	>-<	a-h
19	=> -~- .DESCRIPTION	description	>- <	1-9
20	=> -~- .ROOMS_BEHIND	rooms_behind	>- <	code

(=> '-' if facade do not exist)

* PLACING : The placement (code a-h) for a south oriented +/- 45 deg facade which is usable for a passive solar installation.

* DESCRIPTION : One or two of the following codes :
1 = Ordinary plane facade.
2 = Projecting balconies.
3 = Integrated (sunked) balconies.
4 = External gallery.
5 = Facade can not be extended.
6 = < 20 cm can be added to the facade.
7 = < 2 m -~-
8 = < 5 m -~-
9 = > 5 m -~-

* ROOMS_BEHIND : One, maximum four of the following codes :
L = Living room.
S = Sleeping room.
C = Conservatory.
K = Kitchen.
Z = Service area, toilet,staircase etc.
W = Office.

SAMPLE NUMBER _ _ _. (sectional elevation) Page 3 out of 9 pages.

21	=>SOLARFACADE1.TYPE.OUTER_LEAF	SOLARFACADE1 type outer	>2<	code
22	=> -~- .TYPE.CAVITY	type cavity	>9<	code
23	=> -~- .TYPE.INNER_LEAF	type inner	>2<	code
24	=>SOLARFACADE1.THICKNESS.OUTER_LEAF	thick outer	>11<	cm
25	=> -~- .THICKNESS.CAVITY	thick cavity	> 8<	cm
26	=> -~- .THICKNESS.INNER_LEAF	thick inner	>11<	cm
27	=>SOLARFACADE2.TYPE.OUTER_LEAF	SOLARFACADE2 type outer	>-<	code
28	=> -~- .TYPE.CAVITY	type cavity	>-<	code
29	=> -~- .TYPE.INNER_LEAF	type inner	>-<	code
30	=>SOLARFACADE2.THICKNESS.OUTER_LEAF	thick outer	> 0<	cm
31	=> -~- .THICKNESS.CAVITY	thick cavity	> 0<	cm
32	=> -~- .THICKNESS.INNER_LEAF	thick inner	> 0<	cm

* TYPE : One of the following codes :

- = Does not exist.
1 = Concrete.
2 = Tile.
3 = Hollow tile.
4 = Areated concrete.
5 = Board, thin/lightweight.
6 = Half-timbering.
7 = Air (only for cavity).
8 = Insulation.
9 = Retrofit insulation.

Wall description :

```
     |-------|******|////////|
out- |-------|******|////////| in-
side |-------|******|////////| side
     |-------|******|////////|
      Outer   Cavity  Inner
      leaf.           leaf.
```

* THICKNESS : The thickness in cm of the structural member,

33	=>THERMAL_INERTIA_NUMBER Z	THER.INERTIA Z	>0.6<_	0.2-0.8

Z = 0.2 : Very light building.
0.4 : Light building.
0.6 : Heavy building.
0.8 : Very heavy building.

SAMPLE NUMBER _ _ _. (sectional elevation) Page 4 out of 9 pages.

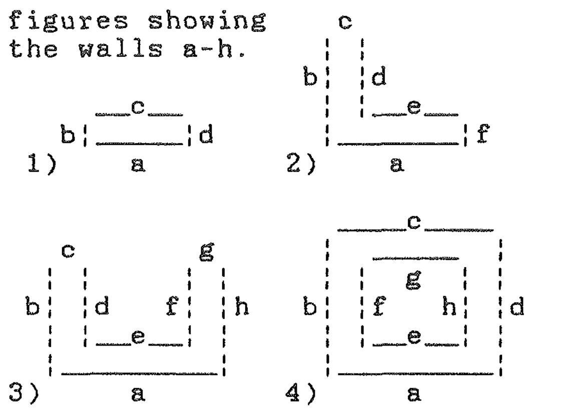
34	=>	SOLARROOF1.PLACING	SOLARROOF1 placing	>a<	a-h
35	=>	-~- .TYPE	type	>2<	1-5
36	=>	-~- .TILT (0-90 deg)	tilt	>47<	deg
37	=>	-~- .DISTANCE RIGDE	distance	> 4 <	m
38	=>	-~- .NUMBER_BAYWINDOWS	numb. baywin	> 2<	0-30
39	=>	-~- .INSULATION_THICKNESS	insul. thick	> ?<	cm
40	=>	-~- .GLASS_AREA	glass area	> 4.4<	m*m
41	=>	SOLARROOF2.PLACING	SOLARROOF2 placing	>-<	a-h
42	=>	-~- .TYPE	type	>-<	1-5
43	=>	-~- .TILT (0-90 deg)	tilt	> 0<	deg
44		.DISTANCE RIGDE	distance	> 0 <	m
45	=>	-~- .NUMBER_BAYWINDOWS	numb. baywin	> 0<	0-30
46	=>	-~- .INSULATION_THICKNESS	insul. thick	> 0<	cm
47	=>	-~- .GLASS_AREA	glass area	> 0 <	m*m

* PLACING : -The code (a-h) for a south oriented +/- 45 deg larger roof surface, usable for a active or passive solar installation.
-For the placing write the letter for the facade whereto the roof tilt.
-For flat roofs write the code for solarfacade1.
-(=> '-' if no such roofsurface exist).

* TYPE :

```
 ___      ___     ___
|___|    /   \   A   A    /]    /\/\
  1        2       3       4      5
```

* TILT : -The tilt of the roof. (0-90 deg).
* NUMBER BAYWIN: -The number of baywindows (not for flat roofs).
* INSUL.THICK : -The thickness of the insulation in the roof.
* GLASS_AREA : -Transparent glass area.
-Windows following the slope of the roof.
-Skylights included, but baywindows excluded.

48	=> FACADE_GLASS_AREA[a..h]	GLASS AREA a	> 7.6<	m*m
49	=> figures showing the walls a-h. 	b	> 9.8<	m*m
50	=>	c	> 5.7<	m*m
51	=>	d	> 3.9<	m*m
52	=>	e	> 0 <	m*m
53	=>	f	> 0 <	m*m
54	=>	g	> 0 <	m*m
55	=>	h	> 0 <	m*m
	(=> '-' if facade does not exist)			
56	=> ROOM_HEIGHT from floor to floor for solarfacade1.	ROOM height	>288<	cm
57	=> HOUSE_HEIGHT from ground level to the roof of the uppermost inhabited room on solarfacade1	HOUSE height	> 3.5<	m
58	=> NUMBER_INHABITED_STOREYS	INHAB.STOREY number	> 2<	0-30

SAMPLE NUMBER _ _ _. (on site) Page 6 out of 9 pages.

59	=>SOLARFACADE1.WINDOW.TYPE	WINDOW type	>2<	1-5
60	=> -~- .WINDOW.COWER	type	>-<	1-3
61	=> -~- .SHADING H	distance	> 10<	cm
62	=> -~- .SHADING D	distance	> 5<	cm
63	=>SOLARFACADE2.WINDOW.TYPE	WINDOW type	>-<	1-5
64	=> -~- .WINDOW.COWER	type	>-<	1-3
65	=> -~- .SHADING H	distance	> 0<	cm
66	=> -~- .SHADING D	distance	> 0<	cm

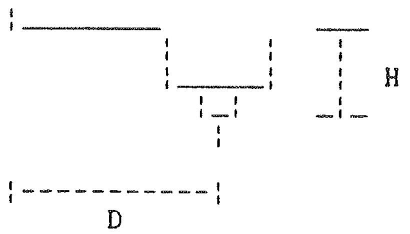
* WINDOW.TYPE :

1 = One layer glass.
2 = 2 layers.
3 = 3 layers.
4 = 2 layer ,Coated
5 = 3 layer ,Coated
6 = 2 layer ,one storm window
7 = 3 layer ,one storm window

* WINDOW.COVER :

\- = No cover.
1 = Horizontal louvres.
2 = Outside awing.
3 = Shutters.

* SHADING H and D



67	=> MUNICIPALITY (see notes)	MUNICIPALITY code	>261<	
68	=> HOUSE_ADDR.ROAD	>Ørnebjergvej <		max: 20chr
69	=> -~- .NUMBER	>50 <		5chr
70	=> -~- .LANDREGISTER	>10 Bo Glostrup <		20chr
71	=> OWNER_ADDR.FIRST_NAME	>Fam. <		max: 12chr
72	=> -~- .FAMILY_NAME	>Sørensen <		15chr
73	=> -~- .ROAD	>Ørnebjergvej <		20chr
74	=> -~- .NUMBER	>50 <		5chr
75	=> -~- .POSTAL_CODE	>2600<		4dig
76	=> -~- .MUNICIPALITY	>Glostrup <		15chr
77	=> -~- .TELEPHONE	>02450691<		8dig
78	=> OWNER_SHIP code	OWNNER SHIP code	>1<	1-9
	1 = Private person or partnership. 2 = Public utility building society. 3 = Joint-stock/share company. 4 = Privat co-operative society. 5 = Other associations or private foundations. 6 = Municipality owned. 7 = County. 8 = Government. 9 = Anything else f.ex ownerflats etc.			
79	=> HOUSE_USE code 110 = Farmhouse. 120 = Single-family houses. 130 = Terrace or aligned house 140 = Multi-family residence 150 = Dormitory	HOUSE_USE code	>140<	110-150

SAMPLE NUMBER _ _ _. (heat inspection report) Page 8 out of 9 pages.

80	=> YEAR.CONSTRUCTION	YEAR construction	>1948<	year
81	=> YEAR.EXTENTION has been made.	extention	>- <	year
82	=> NUMBER_OF_EXTENTIONS see above.	EXTENTIONS number of	>0<	0-9
83	=> NUMBER_DWELLINGS.OWNED	NR DWELLINGS owned	> 1<	0-999
84	=> -~- .RENTED	rented	> 1<	0-999
85	=> AREA.LIVING	AREA living	> 151<	m*m
86	=> AREA.COMMERCIAL	commercial	> 0<	m*m
87	=> AREA.ATTIC	attic	> 66<	m*m
88	=> AREA.BASEMENT (not crawl)	basement	> 85<	m*m
89	=> HEATING_SYSTEM type (see notes)	HEATING system	>43 <	code 1-122
90	=> ENERGY.ANNUAL_CONSUM	ENERGY annu. consum	> 3 <	amoun
91	=> -~- .UNIT (for above)	unit	>m<	code
	* UNIT : J = GJ/year L = 1000 l/year C = Gcal/year M = 1000 kbm/year W = Mwh/year G = 1000 kg/year T = 1000 tons/year			
92	=> ENERGY.ANNUAL_SAVING ,1000 kr	ENERGY annu. saving	> 0.24<	10^3 kr
93	=> -~- .INVESTMENT ,1000 kr	investment	> 1.95<	10^3 kr
	The annual saving = the brutto-saving on the energy expenses with the proposed investment in energy saving measures.			

Fig 16. Heat balance of windows in the heating season.

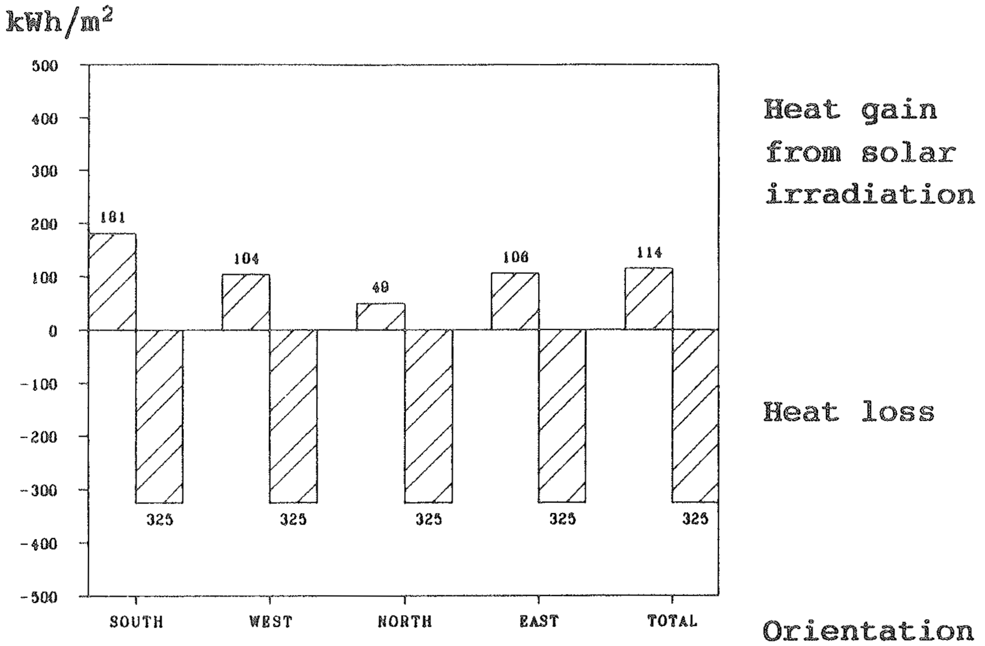


Fig 17. Heat balance for windows. Positive/Negative

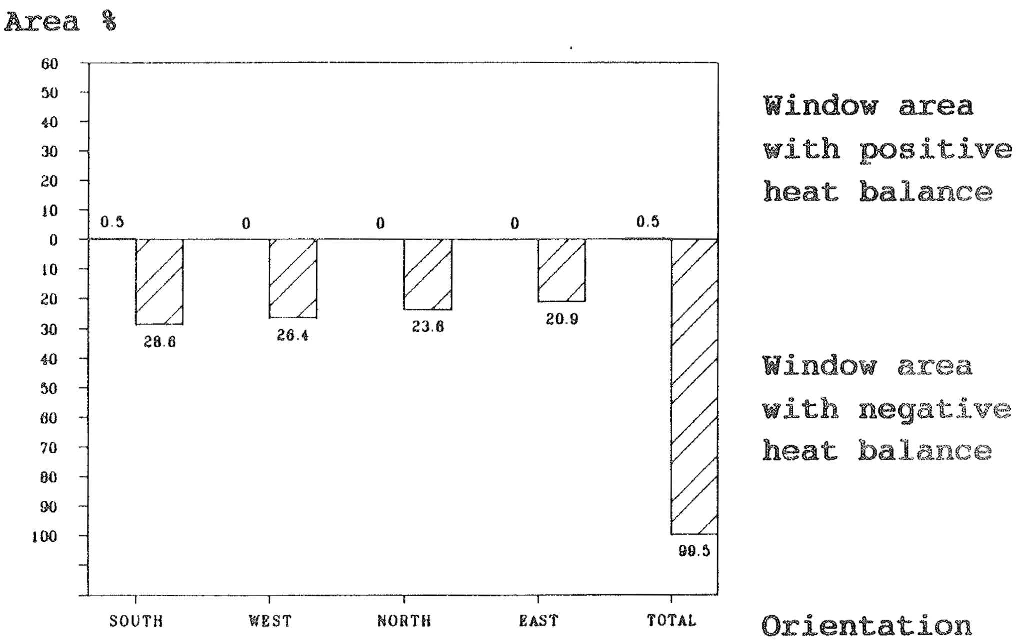


Fig 16. and 17. show that almost none of the investigated windows at the present have a positive heat balance i the heating season.

9.2. MODIFIED WINDOW CONSTRUCTION

There have been looked at six different measures.

9.2.1. Addition of an extra layer of glass to an existing one layer construction.

Objectives - All buildings with one layer of glass in the existing window construction.
Number of buildings found : 2
Area / total area of windows : 23 %

Investment - Little.

Benefits - Calculated to an average saving of 29 % per building involved, which is an overall saving of 6 %.

9.2.2. Addition of an extra layer of glass to existing one or two layer construction.

Objectives - All buildings with two layers of glass or less in the existing window construction.
Number of buildings found : 64
Area / total area of windows : 96 %

Investment - Little.

Benefits - Calculated to an average saving of 12 % per building involved, which is an overall saving of 11 %.

Economy - Medium. Case dependent.

SAMPLE NUMBER _ _ _. (heat inspection report) Page 9 out of 9 pages.

94	=> SOLARFACADE1.OVERSHADOWING	SOLARFACADE factor	>0.3 <	0-1
95	=> SOLARFACADE1.OVERSHADOWING-TREES	factor	>0.17<	0-1
96	=> SOLARGACADE1.AREA	area	> 28.4<	0-999
97	=> SOLARFACADE2.OVERSHADOWING	factor	>0 <	0-1
98	=> SOLARFACADE2.OVERSHADOWING-TREES	factor	>0 <	0-1
99	=> SOLARGACADE2.AREA	area	> 0 <	0-999
100	=> SOLARROOF1.OVERSHADOWING	SOLERROOF factor	>0.24<	0-1
101	=> SOLARROOR1.OVERSHADOWING-TREES	factor	>0.12<	0-1
102	=> SOLARROOF1.AREA	area	> 56.2<	0-999
103	=> SOLARROOF2.OVERSHADOWING	factor	>0 <	0-1
104	=> SOLARROOR2.OVERSHADOWING-TREES	factor	>0 <	0-1
105	=> SOLARROOF2.AREA	area	> 0 <	0-999
106	=> INHABITANTANSWAR.DRAPES ?	yes or no	>j<	y or n
107	=> INHABITANTANSWAR.REASON ? *		> 23<	1-5

* Code : One. max four of the following :

- : No reason
1 : To protect furniture
2 : Because it gets too hot
3 : To avoid people looking in
4 : It looks nice
5 : Other reasons

Comments on the different information in the survey questionnaire :

The information is gathered from various sources:

1) Deposited plans.
2) On-site investigations.
3) Heat inspection report.
4) Result of photographic investigation (On-site investigations).
5) Reply letter from inhabitants.

Item 1-14 : Source 1) — Basic information on general geometry of investigated house.

Item 14 : Basement type is useful to know for possible heat storage space for some purposes.

Item 15-33 : Placing and description of possible useful
Source 1),2) facade for passive solar measurements.

Item 16,19 : Is used to describe constructional problems and to indicate free area for possible attachment to the wall such as glass covering and attached sunspaces.

Code 2,3: Glass covering of balconies might be possible, if problems with fire fire escabe routes are solved.

Code 5 : Only the window construction can be modified.

Code 6 : Solar walls can be applied.

Code 7 : Small sunspaces can be added.

Code 8,9: Large conservatories can be added.

Rooms behind :

Code L,S: Full savings from passive solar measures.

Code K,Z: Reduced benefits.

Code C : Existing passive solar energy utilization.

Code W : Limited utilization possibilities.

Item 21,24,27,30 : Outer leaf of wall :

Code 1-3: Usable for storage in solar walls (mass or Trombe wall).

Code 4-6: Not usable for Trombe wall.

Code 7,8: Usable or not usable for circulation of air (ventilated solar wall) or for modification to Trombe wall.

Code 8,9: Not usable for Trombe wall.

Item 23,26,29,32 : Inner leaf of wall :

In combination with outer leaf can the possibilities of using Trombe walls be investigated.

Item 33 : Thermal inertia :

0.2-0.4 : If window areas are large a larger thermal inertia could be considered.

0.6-0.8 : A large heat storage already present.

Item 34-47 : Solar roof. Possibilities for utilizing roof space collectors or active solar collectors.

Source 1),2)

Item 36,43 : Tilt lower than 20^0 makes it difficult to use the existing roof construction.

Item 38,40,45,47 : Indicates that the roof space is utilized for living (in case of a sloping roof).

Item 37,37,43,44 : Makes it possible to calculate the area of the roof, which might be available for roof space and active solar collectors.

Item 39,46 : Indicates if additional insulation might be necessary.

Item 48-55 : Glass area. Simple rules.
Source 1)

Facade facing :

South : Window area sufficient if greater than 10 % of floor area.

South/East/West : Not advantageous to increase window area if the area is greater than 20 % of floor area.

South : In combination with other passive solar measures the window area should be less than 15 %.

North : Reduction of north facing or overshadowed window area should be considered if the window area is greater than 10 % of floor area.

Item 56,57 :
Source 1)

Item 56 : Room height. If greater than 2.4 m then it probably is possible to install ventilation duct.

Item 57 : House height. Useful for determination of effective incident solar radiation and area of solar facade.

Item 59-66 : Average window type.
Source 2)

Item 59,63 : Code 1 : Improvement of window construction recommendable.

Item 60,64 : Use of window covers for shading.

Item 61,62,65,66 :
Useful for determination of the overshadowing from window overhangs.

Item 76-85 : General information for useful statistical analysis and gathering of information.
Source 3)

Item 86-88 :
Source 3)

Item 86 : Commercial area might accept less solar apenture areas.

Item 87 : Attic area could be used for roof space collectors.

Item 88 : Basement could be used for placement of heat storage.

Item 90-93 : Heating type and cost.
Source 3)

Item 92,93 : Shows the potential for further reductions of energy consumption and cost of the investments.

Item 94-105 : Overshadowing of facades and roofs.
Source 1),4)

A solar facade or roof is defined as a facade or roof which might give access to passive solar measures. The general requirement is that the facade or roof is oriented south +/- 45^0.

Item 95,98,101,104 :
Hyphotetical value of overshadowing if all neighboring trees were cut.

Item 106-107 : Inhabitant's use of curtains.
Source 5)

Some passive solar measures might call for the inhabitants to shade to avoid overheating.

APPENDIX B : PHOTO FORM

<u>Purpose :</u>

On-site	-	Noting picture numbers, film numbers and making small plan drawing.
At projector	-	When the pictures are projected down on the sheets to fill in the percentages overshadowed, approximate distances and tree codes (1 for decidouos and nothing for evergreens).

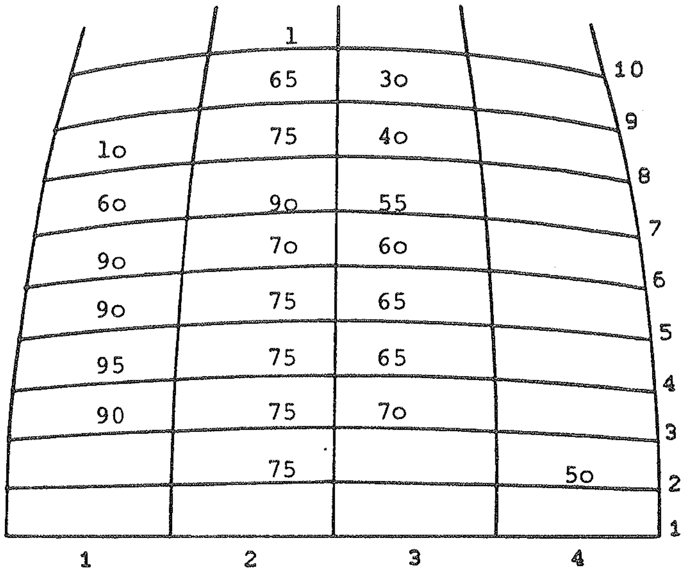
<u>Comments :</u>

General	:	Each rectangular enclosure encompasses 5° vertically and 15° horizontally.
Overshadowing	:	Every unnoted rectangular enclosure below a filled-out one is denoted as 100 %, except if the filled-out one is 0 % (see column 5,4). Column 10 is a repeater 1 to 5 of the percentages in the rectangular enclosure column 9. This additional information outside the 45° vertical picture field is used in the cases, where the transformation of view point with big difference between height of camera and distance to middle of the facade (the resulting view point) requires this information.
Distances	:	Objects in the same rectangular enclosure are denoted the distance, which is the largest.
Tree indication	:	Only deciduous trees are recorded, as their overshadowing effect varies depending on the time of year.

PICTURE UNDERLAY   OVERSHADOWING

SURVEY NUMBER : S 82
OBJECT NAME : SF2
HEIGHT TO MIDDLE OF OBJECT : 2.oo
AZIMUTH :
HEIGHT OF CAMERA, M : 1.4o
CAMERA DISTANCE TO WALL : 2.85

LEFT PICTURE NUMBER : 82o4



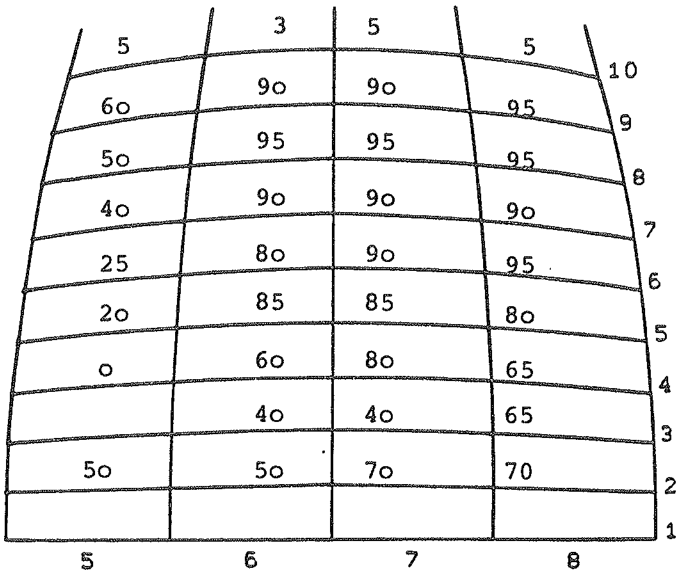
FILM NUMBER : 21   PICTURE NUMBER : 82o4

DATE :

PICTURE UNDERLAY — OVERSHADOWING

SURVEY NUMBER : S 82
OBJECT NAME : SF2

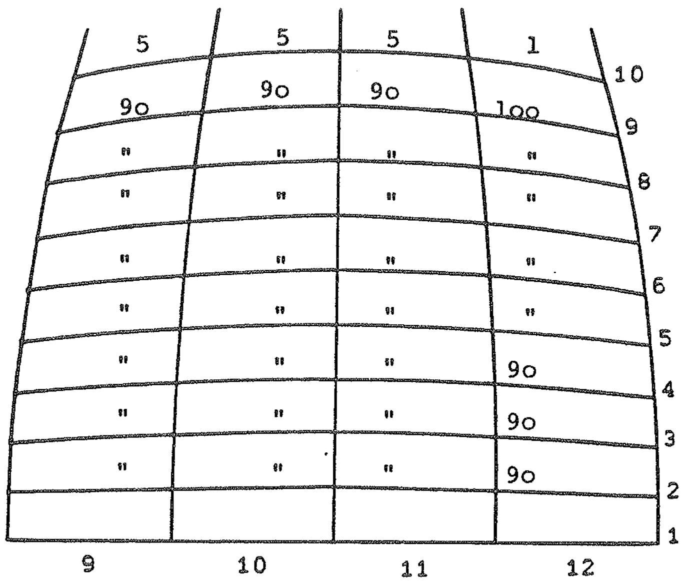
MIDDLE PICTURE NUMBER : 82o5



FILM NUMBER : 22 PICTURE NUMBER :

SURVEY NUMBER : S 82
OBJECT NAME : SF2

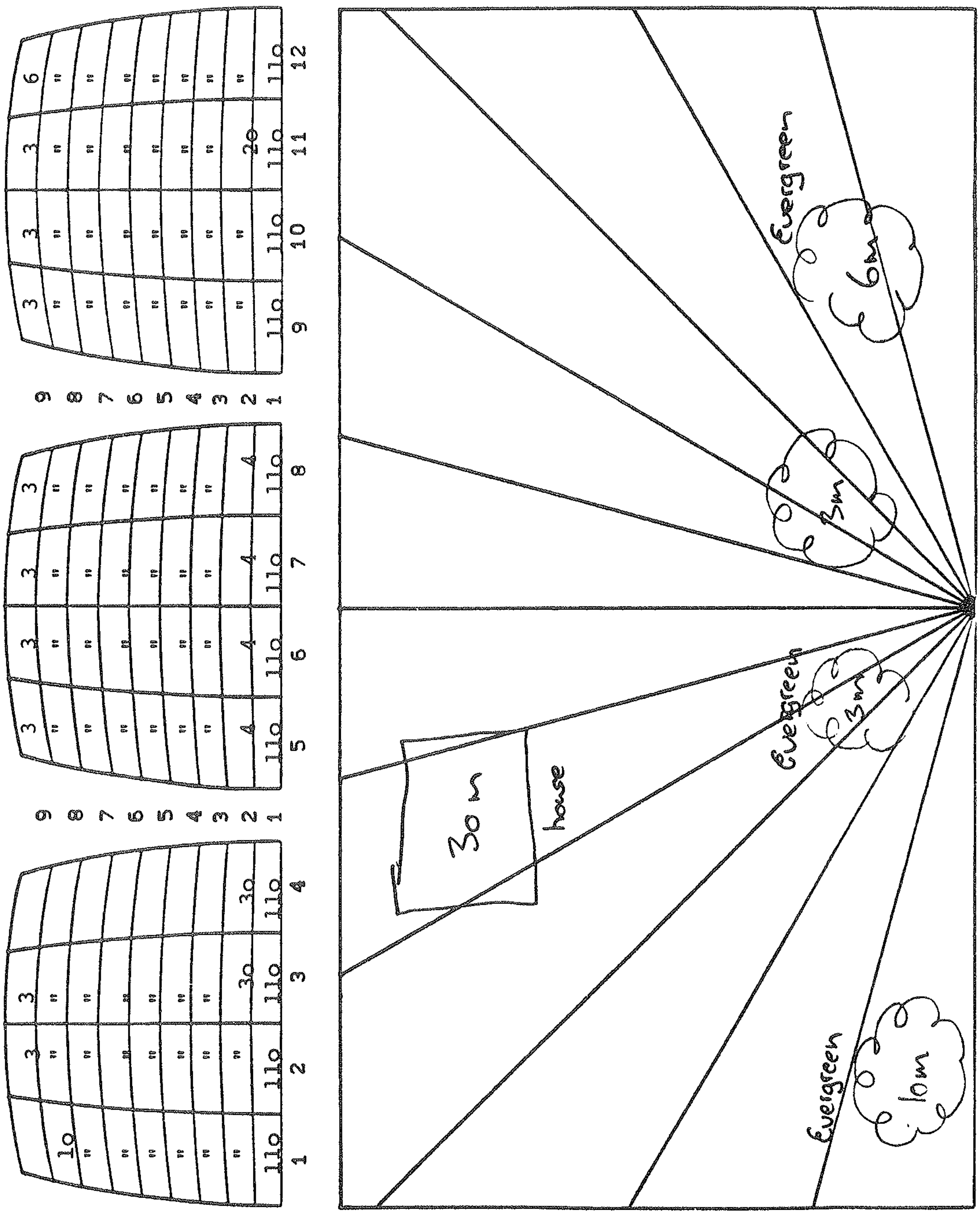
RIGHT PICTURE NUMBER : 82o6



FILM NUMBER : 23 PICTURE NUMBER : 82o6

PICTURE UNDERLAY DISTANCES

SURVEY NUMBER : S 82
OBJECT NAME : SF2



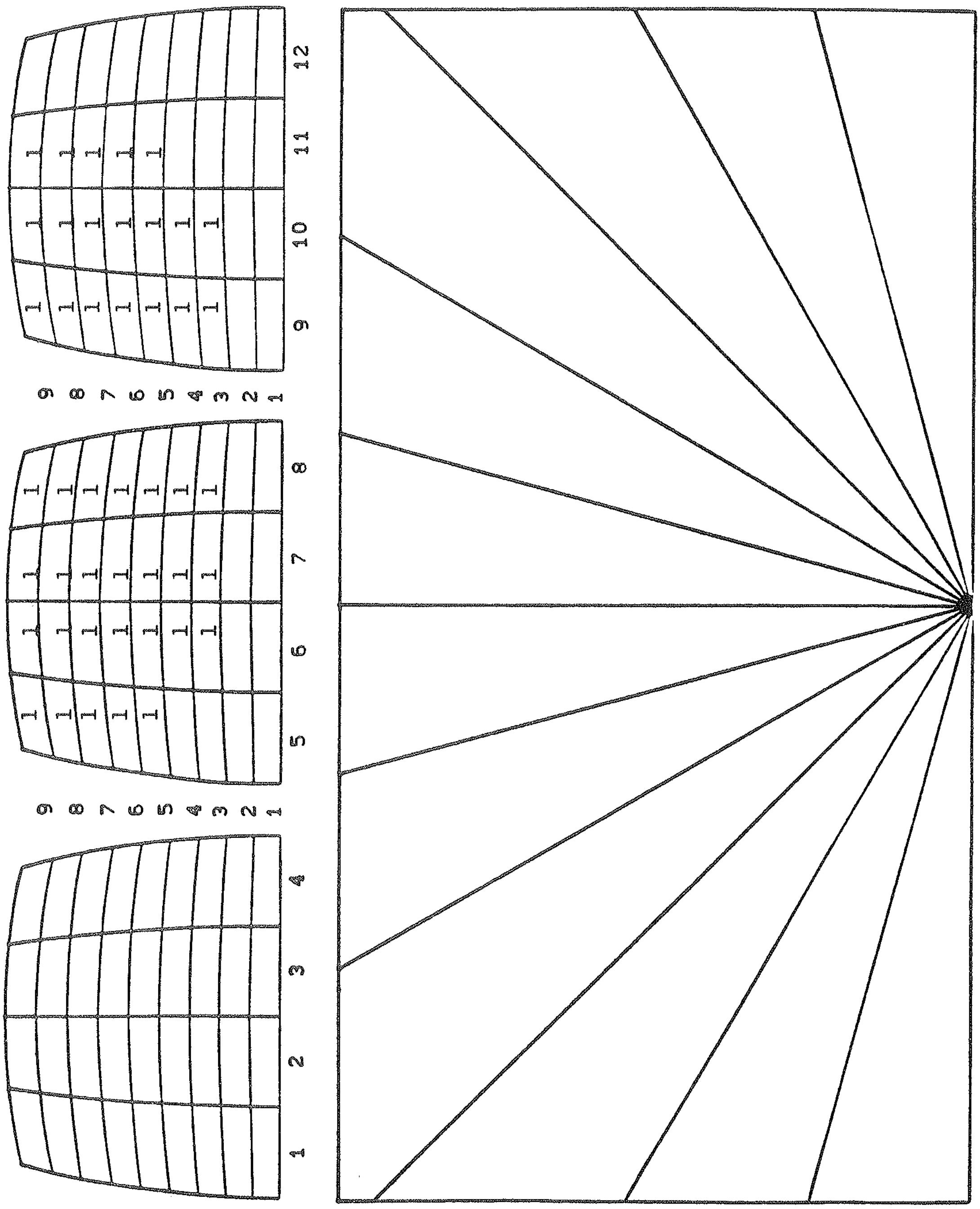
PICTURE UNDERLAY

TREE-INDICATIONS

SURVEY NUMBER : S 82

OBJECT NAME : SF2

INDICATION : 1 or 0 (Not Evergreens)



APPENDIX C : OPTICAL TRANSFORMATION OF LENS

For making the overlay grid in the photo form it was necessary to establish the optical transformation of the image through the fish-eye lens, the camera and the projector used. The Nikkor fish-eye lens used consists of five individual lenses which makes this very complicated. Furthermore the sale specifications are somewhat popular and not for scientific use. This led to three options :

1) To contact importers and dealers of Nikon cameras.

2) To send all used photo equipment to a full investigation by experts in these matters. The Technical University of Denmark has an institute of photogrammetry which can make such an investigation.

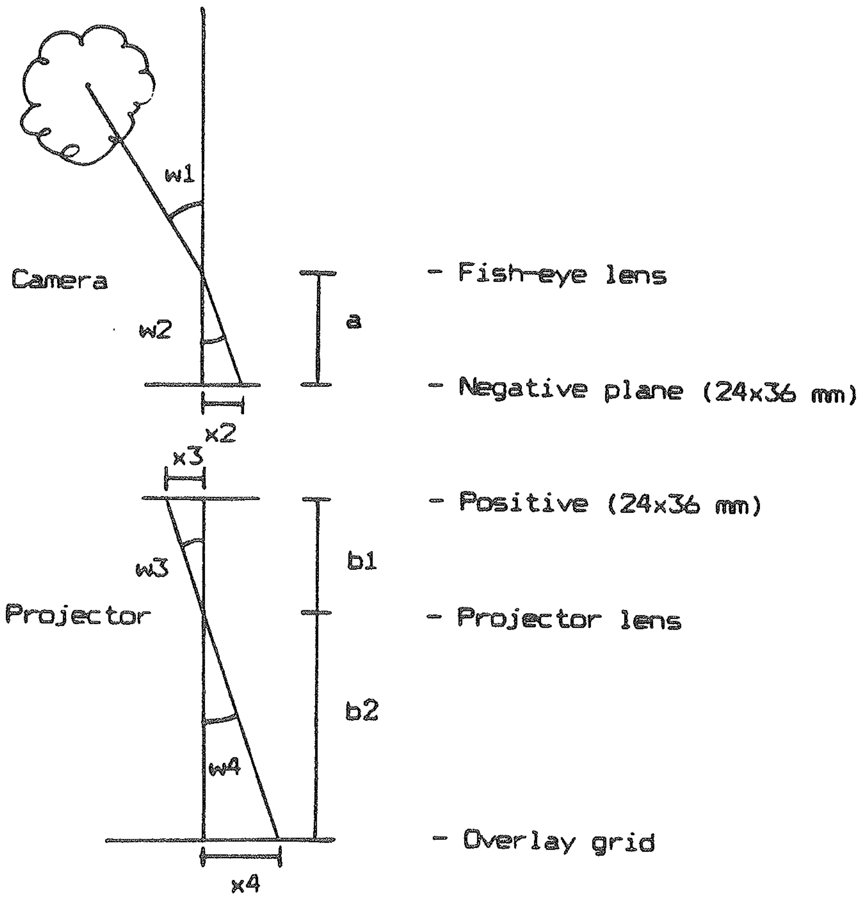
3) To make a series of tests ourselves.

The dealer and importer of Nikon equipment were contacted but could not provide any additional information. They recommended to contact Nikon in Japan but this was considered too laborious.
The Institute for Photogrammetry were helpful, but a full investigation of the equipment would be very expensive and time consuming. It was therefore decided to establish the transformation ourselves. Two tests have been completed :

1) An indoor photo series of a measuring board.
2) An outdoor photo series of measuring points.

The indoor investigation had the advantage of having a precisely defined image, but as the distortion through the fish-eye lens is very big the camera had to be placed very near the measuring board leaving a great uncertainty regarding the measured distances. The outdoor investigation was more precise but more complicated as the measuring points had to be established using a theodolite. The investigation also allowed to check the transformation of the overshadowing profile by changing view point as the camera was placed in front of a normal house. In order to use the investigation photos the theory of transformation had to be simplified showed Fig C1.

Fig C1



Simplified theory :

w1/w2=c1 (c1 constant)
x2=a*tan(w2) (a constant)
w3/w4=c2 (c2 constant)
x3=b1*tan(w3)
x4=b2*tan(w4)

The image on the overlay grid is found by :

w2=w1/c1
x2=a*tan(w2)
x3=x2
w3=Arctan(x3/b1)
w4=w3/c2
x4=b2*tan(w4)

For the projector used :

b1=50 mm	Given
b2=301 mm	Used for the particular photo form
c2=1.018	Distortion found by test

For the camera with fish-eye lens :

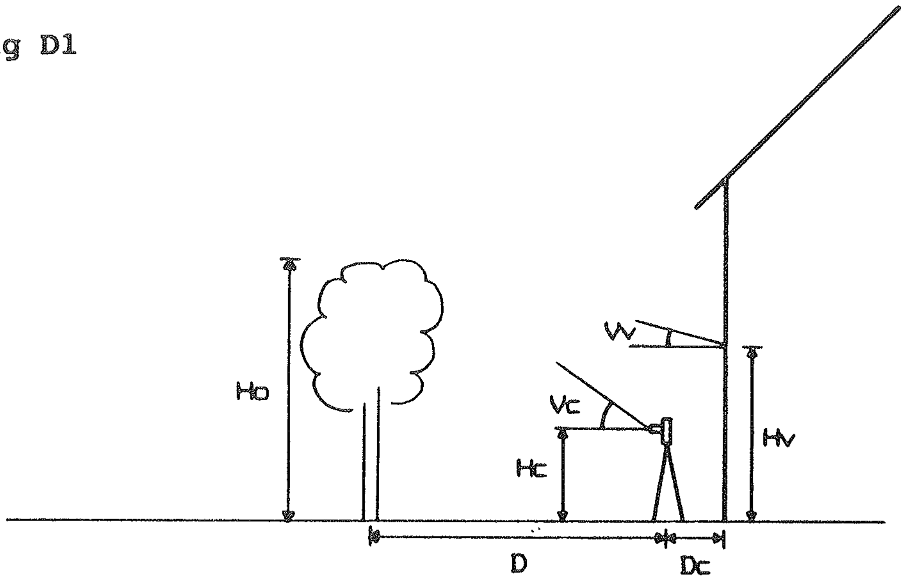
a=86.65 mm	Camera constant found by test
c1=5.453	Distortion found by test

The used 16 mm. fish-eye lens was originally selected for the purpose of taking only two pictures to cover a 180^0 profile horizontally. The lens specification stated that one picture would cover 153^0 vertically and 106^0 horizontally. But this must be at edge of the image, depending on the camera used or directly misleading because the image obtained by the described arrangement does only cover 128^0 vertically and 86^0 horizontally requiring three pictures to be taken per facade.

APPENDIX D : TRANSFORMATION OF OVERSHADOWING DATA

The view point of the overshadowing profile was selected at the center of a facade or a roof causing the photo data to be transformed. For this a special computer program has been made.

Fig D1



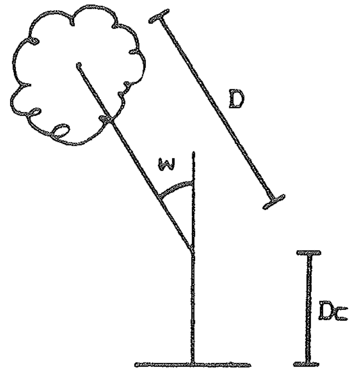
Ho	:	Hight of object.
D	:	Distance to object.
Hc	:	Hight of camera.
Dc	:	Distance from camera to facade.
Hv	:	Height of view point.
Vc	:	Profile angle from camera.
Vv	:	Profile angle at view point.

<u>Equations :</u>

Vv=Arctan((tan(Vc)+cor1)*cor2)
cor1=(Hc-Hv)/D
cor2=(1/(1+Dc/D))*cor3
cor3=cos(w)

The cor3 is to account for the diversion from the normal to the facade . This is only done in a simplified way as the correction for the distance of the camera to the facade does not have any a great importance.

Fig D1



In the transformation program the percentage filled-out overshadowing in each rectangular enclosure is transferred according to these equations. The program is very advanced having interactive menus for manual correction possibilities making the transformation very efficient. After the correction the profile is multiplied with a tree factor 0.5-0.8 depending on the date of the pictures taken to account for deciduous trees. The final profile is then multiplied with interpolation of the 5 solar charts showed on the next page made by Erwin Petersen (Ref 6) listing the relative reduction of solar gain for each rectangular enclosure in the heating season. For a particular overshadowing profile the reduction percentages are summarized and the result gives the overall reduction factor Fs. If the profile does not have to be interactively corrected the whole operation only takes a few seconds.

Relative reduction % of solar gain through a double glazed window in the heating season. Each enclosure 30^0 horizontally and 5^0 vertically.

The five overshadowing charts used :

For facade facing :

South-60^0

0.0	0.5	0.5	2.5	1.0	0.5
0.0	0.5	1.0	2.5	1.5	0.5
0.0	0.5	2.0	2.5	2.0	0.5
0.5	0.5	2.0	3.0	3.0	0.5
0.5	0.5	3.0	4.0	3.5	0.5
0.5	1.0	3.5	3.5	5.0	1.0
0.0	1.5	1.5	3.5	3.0	1.5
0.0	0.5	1.5	4.0	4.0	0.5
0.0	0.5	1.0	1.0	1.0	0.5

South-30^0

0.0	1.0	2.0	1.0	2.0	0.0
0.0	1.0	2.0	2.0	2.0	0.5
0.0	1.0	2.0	2.5	2.0	0.5
0.0	1.0	2.0	3.0	2.0	0.5
0.0	1.5	3.0	4.0	2.0	0.5
0.5	1.5	4.0	4.5	2.0	0.5
0.5	1.0	3.0	4.5	4.0	0.5
0.5	1.0	2.5	4.0	3.0	0.5
0.0	0.5	1.0	1.0	1.0	0.5

South

0.0	1.5	2.0	2.0	1.5	0.0
0.0	1.5	2.0	2.0	1.5	0.0
0.5	1.5	2.0	2.0	1.5	0.5
0.5	1.5	3.0	3.0	1.5	0.5
0.5	2.0	3.5	3.5	2.0	0.5
0.5	2.5	3.5	3.5	2.5	0.5
0.5	2.0	4.0	4.0	2.0	0.5
0.0	2.0	4.0	4.0	2.0	0.0
0.0	1.0	1.0	1.0	1.0	0.0

South+30^0

0.0	2.0	1.0	2.0	1.0	0.0
0.5	2.0	2.0	2.0	1.0	0.0
0.5	2.0	2.5	2.0	1.0	0.0
0.5	2.0	3.0	2.0	1.0	0.0
0.5	2.0	4.0	3.0	1.5	0.0
0.5	2.0	4.5	4.0	1.5	0.5
0.5	4.0	4.5	3.0	1.0	0.5
0.5	3.0	4.0	2.5	1.0	0.5
0.5	1.0	1.0	1.0	0.5	0.0

South+60^0

0.5	1.0	2.5	0.5	0.5	0.0
0.5	1.5	2.5	1.0	0.5	0.0
0.5	2.0	2.5	2.0	0.5	0.0
0.5	3.0	3.0	2.0	0.5	0.5
0.5	3.5	4.0	3.0	0.5	0.5
1.0	5.0	3.5	3.5	1.0	0.5
1.5	3.0	3.5	1.5	1.5	0.0
0.5	4.0	4.0	1.5	0.5	0.0
0.5	1.0	1.0	1.0	0.5	0.0

To indicate the principle of the transformation program some screen pictures of the program are presented on the following pages.

1 INDATA :

SURVEY NUMBER	1	82
PICTURE NUMBERS	2	8204, 8205, 8206
OBJECTNAME	3	SF2
HEIGHT TO MIDDLE OF WALL	4	2.00
AZIMUTH	5	212
HEIGHT OF CAMERA	6	1.40
CAMERA DISTANCE FROM WALL	7	2.85

2 OVERSHADOWING :

0	1	0	0	5	3	5	5	5	5	5	1	
--	0.65	0.30	--	0.60	0.90	0.90	0.95	0.90	0.90	0.90	1.00	9
0.10	0.75	0.40	--	0.50	0.95	0.95	0.95	--	--	--	--	8
0.60	0.90	0.55	--	0.40	0.90	0.90	0.90	--	--	--	--	7
0.90	0.70	0.60	--	0.25	0.80	0.90	0.95	--	--	--	--	6
0.90	0.75	0.65	--	0.20	0.85	0.85	0.80	--	--	--	--	5
0.95	0.75	0.65	--	0.00	0.60	0.80	0.65	--	--	--	0.90	4
0.90	0.75	0.70	--	--	0.40	0.40	0.65	--	--	--	0.90	3
--	0.75	--	0.50	0.50	0.50	0.70	0.70	--	--	--	0.90	2
--	--	--	--	--	--	--	--	--	--	--	--	1
1	2	3	4	5	6	7	8	9	10	11	12	

3 DISTANCE FROM CAMERA :

--	3	3	--	3	3	3	3	3	3	3	6	9
10	3	3	--	3	3	3	3	3	3	3	6	8
10	3	3	--	3	3	3	3	3	3	3	6	7
10	3	3	--	3	3	3	3	3	3	3	6	6
10	3	3	--	3	3	3	3	3	3	3	6	5
10	3	3	--	--	3	3	3	3	3	3	6	4
10	3	3	--	--	3	3	3	3	3	3	6	3
10	3	30	30	4	4	4	4	3	3	20	6	2
110	110	110	110	110	110	110	110	110	110	110	110	1
1	2	3	4	5	6	7	8	9	10	11	12	

4 TREE-INDICATION (NOT EVERGREENS) :

--	--	--	--	1	1	1	1	1	1	1	--	9
--	--	--	--	1	1	1	1	1	1	1	--	8
--	--	--	--	1	1	1	1	1	1	1	--	7
--	--	--	--	1	1	1	1	1	1	1	--	6
--	--	--	--	1	1	1	1	1	1	1	--	5
--	--	--	--	--	1	1	1	1	1	--	--	4
--	--	--	--	--	1	1	1	1	1	--	--	3
--	--	--	--	--	--	--	--	--	--	--	--	2
--	--	--	--	--	--	--	--	--	--	--	--	1
1	2	3	4	5	6	7	8	9	10	11	12	

5 OVERSHADOWING AFTER AUTOMATIC RESTFILL :

1	2	3	4	5	6	7	8	9	10	11	12	
--	--	--	--	0.60	--	0.90	0.95	0.90	0.90	0.90	--	14
--	--	--	--	0.60	--	0.90	0.95	0.90	0.90	0.90	--	13
--	--	--	--	0.60	0.90	0.90	0.95	0.90	0.90	0.90	--	12
--	--	--	--	0.60	0.90	0.90	0.95	0.90	0.90	0.90	--	11
--	0.65	--	--	0.60	0.90	0.90	0.95	0.90	0.90	0.90	1.00	10
--	0.65	0.30	--	0.60	0.90	0.90	0.95	0.90	0.90	0.90	1.00	9
0.10	0.75	0.40	--	0.50	0.95	0.95	0.95	1.00	1.00	1.00	1.00	8
0.60	0.90	0.55	--	0.40	0.90	0.90	0.90	1.00	1.00	1.00	1.00	7
0.90	0.70	0.60	--	0.25	0.80	0.90	0.95	1.00	1.00	1.00	1.00	6
0.90	0.75	0.65	--	0.20	0.85	0.85	0.80	1.00	1.00	1.00	1.00	5
0.95	0.75	0.65	--	--	0.60	0.80	0.65	1.00	1.00	1.00	0.90	4
0.90	0.75	0.70	--	--	0.40	0.40	0.65	1.00	1.00	1.00	0.90	3
1.00	0.75	1.00	0.50	0.50	0.50	0.70	0.70	1.00	1.00	1.00	0.90	2
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1

6 DISTANCE FROM CAMERA AFTER AUTOMATIC RESTFILL :

1	2	3	4	5	6	7	8	9	10	11	12	
--	--	--	--	3	--	3	3	3	3	3	--	14
--	--	--	--	3	--	3	3	3	3	3	--	13
--	--	--	--	3	3	3	3	3	3	3	--	12
--	--	--	--	3	3	3	3	3	3	3	--	11
--	3	--	--	3	3	3	3	3	3	3	6	10
--	3	3	--	3	3	3	3	3	3	3	6	9
10	3	3	--	3	3	3	3	3	3	3	6	8
10	3	3	--	3	3	3	3	3	3	3	6	7
10	3	3	--	3	3	3	3	3	3	3	6	6
10	3	3	--	3	3	3	3	3	3	3	6	5
10	3	3	--	--	3	3	3	3	3	3	6	4
10	3	3	--	--	3	3	3	3	3	3	6	3
10	3	30	30	4	4	4	4	3	3	20	6	2
110	110	110	110	110	110	110	110	110	110	110	110	1

7 TREE-INDICATION (NOT EVERGREENS) AFTER AUTOMATIC RESTFILL :

1	2	3	4	5	6	7	8	9	10	11	12	
--	--	--	--	1	--	1	1	1	1	1	--	14
--	--	--	--	1	--	1	1	1	1	1	--	13
--	--	--	--	1	1	1	1	1	1	1	--	12
--	--	--	--	1	1	1	1	1	1	1	--	11
--	--	--	--	1	1	1	1	1	1	1	--	10
--	--	--	--	1	1	1	1	1	1	1	--	9
--	--	--	--	1	1	1	1	1	1	1	--	8
--	--	--	--	1	1	1	1	1	1	1	--	7
--	--	--	--	1	1	1	1	1	1	1	--	6
--	--	--	--	1	1	1	1	1	1	1	--	5
--	--	--	--	--	1	1	1	1	1	--	--	4
--	--	--	--	--	1	1	1	1	1	--	--	3
--	--	--	--	--	--	--	--	--	--	--	--	2
--	--	--	--	--	--	--	--	--	--	--	--	1

8 OVERSHADOWING AFTER MULTIPLIED TREE-FACTOR :

--	--	--	--	0.48	--	0.72	0.76	0.72	0.72	0.72	--	14
--	--	--	--	0.48	--	0.72	0.76	0.72	0.72	0.72	--	13
--	--	--	--	0.48	0.72	0.72	0.76	0.72	0.72	0.72	--	12
--	--	--	--	0.48	0.72	0.72	0.76	0.72	0.72	0.72	--	11
--	0.65	--	--	0.48	0.72	0.72	0.76	0.72	0.72	0.72	1.00	10
--	0.65	0.30	--	0.48	0.72	0.72	0.76	0.72	0.72	0.72	1.00	9
0.10	0.75	0.40	--	0.40	0.76	0.76	0.76	0.80	0.80	0.80	1.00	8
0.60	0.90	0.55	--	0.32	0.72	0.72	0.72	0.80	0.80	0.80	1.00	7
0.90	0.70	0.60	--	0.20	0.64	0.72	0.76	0.80	0.80	0.80	1.00	6
0.90	0.75	0.65	--	0.16	0.68	0.66	0.64	0.80	0.80	0.80	1.00	5
0.95	0.75	0.65	--	--	0.48	0.64	0.52	0.80	0.80	1.00	0.90	4
0.90	0.75	0.70	--	--	0.32	0.32	0.52	0.80	0.80	1.00	0.90	3
1.00	0.75	1.00	0.50	0.50	0.50	0.70	0.70	1.00	1.00	1.00	0.90	2
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
1	2	3	4	5	6	7	8	9	10	11	12	

9 OVERSHADOWING AFTER HEIGHT CORRECTION :

--	--	--	--	0.48	--	0.72	0.76	0.72	0.72	0.72	--	9
--	--	--	--	0.48	0.37	0.72	0.76	0.72	0.72	0.72	0.28	8
0.03	--	--	--	0.48	0.72	0.72	0.76	0.72	0.72	0.72	1.00	7
0.26	0.27	--	--	0.48	0.72	0.72	0.76	0.72	0.72	0.72	1.00	6
0.64	0.65	0.16	--	0.48	0.72	0.72	0.76	0.72	0.72	0.72	1.00	5
0.90	0.70	0.40	--	0.48	0.72	0.72	0.76	0.74	0.74	0.74	1.00	4
0.82	0.93	0.67	--	0.43	0.82	0.72	0.83	0.80	0.80	0.80	1.00	3
0.90	0.79	0.91	0.33	0.23	0.73	0.76	0.76	0.80	0.80	0.80	0.90	2
1.00	0.75	1.00	0.94	0.94	1.00	1.00	0.52	0.80	0.80	1.00	0.90	1
1	2	3	4	5	6	7	8	9	10	11	12	

10 RESULT AFTER DATA REDUCTION :

--	--	0.24	0.74	0.72	0.36	9
--	--	0.43	0.74	0.72	0.50	8
0.01	--	0.60	0.74	0.72	0.86	7
0.26	--	0.60	0.74	0.72	0.86	6
0.64	0.08	0.60	0.74	0.72	0.86	5
0.80	0.20	0.59	0.74	0.74	0.87	4
0.87	0.34	0.62	0.77	0.80	0.90	3
0.84	0.62	0.48	0.76	0.80	0.85	2
0.88	0.97	0.97	0.76	0.80	0.95	1
1	2	3	4	5	6	

```
11 SHADOW CHART FOR :
AZIMUTH              : 212
-------------------------

  -------------------------------------
  0.03  1.93  1.10  1.90  0.97  0.00 :      9
  0.50  1.97  2.03  1.93  0.97  0.00 :      8
  0.50  2.00  2.50  2.00  0.97  0.00 :      7
  0.50  2.07  3.00  2.00  0.97  0.03 :      6
  0.50  2.10  4.00  3.00  1.43  0.03 :      5
  0.53  2.20  4.43  3.97  1.47  0.50 :      4
  0.57  3.93  4.43  2.90  1.03  0.47 :      3
  0.50  3.07  4.00  2.43  0.97  0.47 :      2
  0.50  1.00  1.00  1.00  0.50  0.00 :      1
  -------------------------------------
   1     2     3     4     5     6


12 RESULT : (1-Fs) % : 46.1                 shadow-angle
---------------------------
:---------------------------------------:   45
:  0.00  0.00  0.26  1.41  0.70  0.00   :
:---------------------------------------:   40
:  0.00  0.00  0.87  1.43  0.70  0.00   :
:---------------------------------------:   35
:  0.01  0.00  1.50  1.48  0.70  0.00   :
:---------------------------------------:   30
:  0.13  0.00  1.80  1.48  0.70  0.03   :
:---------------------------------------:   25
:  0.32  0.17  2.40  2.22  1.03  0.03   :
:---------------------------------------:   20
:  0.43  0.45  2.61  2.93  1.08  0.43   :
:---------------------------------------:   15
:  0.49  1.33  2.75  2.24  0.83  0.42   :
:---------------------------------------:   10
:  0.42  1.90  1.93  1.85  0.77  0.40   :
:---------------------------------------:    5
:  0.44  0.97  0.97  0.76  0.40  0.00   :
:---------------------------------------:    0
122   152   182   212   242   272   302     azimuth
```

The program constantly checks if the data is correct, and makes it possible to correct data interactively using questions like e.g. :

```
PLEASE WAIT
THERE IS MISSING A DISTANCE INFORMATION IN

COLUMN : 1
ROW    : 8
ENTER RIGHT DISTANCE :

ARE THERE ANY FAULTS ?   ( Y or < enter > )
IN WHICH COLUMN ?
5
IN WHICH ROW ?
1
ENTER RIGHT TREE-INDICATION : 0 or 1 , ( NOT EVERGREENS )
1

DURING THE PROGRAM YOU HAVE MADE CHANGES
DO YOU WANT TO SAVE DATA PERMANENTLY ?   ( Y or < enter >)
```

APPENDIX E : HEAT BALANCE OF WINDOWS

The balance can be calculated by :

$$Ue = U - \frac{Qsun * Fs * F * Ft}{\Delta t * N}$$

Where :

Ue	:	Resulting U-value
U	:	Normal U-value
Qsun	:	Solar irradiation through a normal double glazed window in the heating season.
Fs	:	Solar reduction due to overshadowing.
F	:	Reduction due to reduction through glass. (F=1 for a double glazed window).
Ft	:	Coefficient of utilization of transmitted solar irradiation (depends on the thermal inertia Z according to Ref 7).
Δt	:	Difference between indoor (20^{0}C) and outdoor (3.4^{0}C) temperature in the heating season.
N	:	Number of hours in the heating season: 5088.

APPENDIX F : SIMPLE PROGRAM FOR CALCULATING THE ANNUAL HEATING REQUIREMENT

The method used is taken from "Calculations of energy use in smaller buildings" Ref. 7 slightly simplified and adapted to the information contained in the survey questionnaire. The method has the advantage of presenting an acceptable picture of the effect of the proposed heat conserving features as the method incorporates utilization coefficients for solar irradiation, internal heat gains and takes into account the thermal inertia of the building.

Step 1) The specific heat loss is calculated from the different building components and ventilation :

Transmission : $W_t = \Sigma A * U * g$
Ventilation : $W_v = 0.34 * V * n$
Specific heat loss : $W_s = W_t + W_v$ (W/°C)

A : The area of the particular component.
U : U-value.
g : Reduction factor, 1 normally, 0.8 for parts against ground and unheated basement.
V : Volume of building.
n : Air change h^{-1}, here set to 0.5 for all buildings.

The heat loss Q_{tv} is calculated for each month as :

$$Q_{tv} = W_s * (\overline{t}_i - \overline{t}_o) * N / 1000 \quad \text{(kWh/month)}$$

$(\overline{t}_i - \overline{t}_o)$: Difference between mean inside and outside temperature in the month.
N : Number of days in the month.
1/1000 : Conversion of W to kW.

Step 2) Internal heat contributions $Q_i = Q_p + Q_{el} + Q_{hw}$

Persons	:	$Q_p = p * 5.33$	(kWh/month)
Electricity	:	$Q_{el} = 200 + p * 2.66$	(kWh/month)
Hot water	:	$Q_{hw} = 1.25 + p * 1.5$	(kWh/month)

P : Number of inhabitants, here set to 1 per 28 m^2 living area

Q_i varies during the year, but is simplified kept constant in these calculations.

Step 3) External heat contribution $Q_s = \Sigma\ I_s * A * Fres$ (kWh/month)

$Fres = F_g * F_s * F_{sh} * F_w$

I_s : Solar irradiation for each month for different orientations of windows (tabular form).

A : Window area (incl. frame).

F_g : Glass area/A

F_s : Overshadowing factor (see chapter 6)

F_{sh} : Window shading. Tabular form for a lot of different types of shading and orientations, but is here simplified to $F_{sh} = 1.0-D*(0.0056/(H+0.066)+0.015)$

H : Height(cm) of window shading from survey questionnaire.

D : Depth (cm) of window shading from survey questionnaire.

Fw : Glass type reduction factor :

- 1 : Normal two layers of glass.
- 1.1 : One layer of glass.
- 0.9 : Three layers of glass.
- 0.85 : Coated two layer construction.

Step 4) Utilization of internal heat contribution and solar irradiation for extremely heavy building.

$$x = \frac{Q_i + Q_s}{Q_{tv}}$$

η_{min} = Function(x) (Graph form)

In expression form :

$$\eta_{min} = \begin{bmatrix} 1 & \text{For } x < 0.75 \\ 1/x * (0.83 + 0.3 * \ln(x)) & \text{For } 0.75 \leq x \leq 1.75 \\ 1/x & \text{For } 1.75 < x \end{bmatrix}$$

Step 5) Utilization of internal heat contribution for extremely light building.

$$x = \frac{Q_i}{Q_{tv}}$$

η_i = Function(x) (Graph form)

In expression form :

$$\eta_i = \begin{bmatrix} 1 & \text{For } x < 0.2 \\ 1/x * (0.52 + 0.2 * \mathrm{Ln}(x)) & \text{For } 0.2 \leq x \end{bmatrix}$$

Step 6) Utilization of solar irradiation for extremely light building corrected for internal heat contribution.

$$x = \frac{Q_s}{Q_{tv} - \eta_i * Q_i}$$

η_s = Function(x) (Graph form)

In expression form :

$$\eta_s = \begin{bmatrix} 1 & \text{For } x < 0.1 \\ 1/x * (0.33 + 0.1 * \mathrm{Ln}(x)) & \text{For } 0.1 \leq x \end{bmatrix}$$

Step 7) Energy use for extremely heavy building.

$$Q_{min} = Q_{tv} - \eta_{min} * (Q_i + Q_s) \qquad \text{(kWh/month)}$$

Step 8) Energy use for extremely light building.

$$Q_{max} = Q_{tv} - \eta_i * Q_i - \eta_s * Q_s \qquad \text{(kWh/month)}$$

Step 9) Resulting energy use for the actual real building.

$$Q_r = Q_{max} - Z * (Q_{max} - Q_{min}) \qquad \text{(kWh/month)}$$

Z : Thermal inertia as used in survey questionnaire.

The resulting energy use for heating Q_r has been calculated for each month in the heating season (Oct.-April) and summarized. The method has also been used for calculations of the multi-storey buildings, which are out of the limits of the method, but the result has in each case been evaluated and found acceptable for the purposes of this project.