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Norwegian Experience in Reducing the Consumption of Energie for the Heating of Buildings

by

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Introduction

Loss of heat in a building may be due to the permeability of exterior surfaces, to ventilation and on losses in the heating system. In the Scandinavian countries great reductions in energy consumption for the heating of buildings have been obtained by developing efficient and cheap insulating wall, floor and roof constructions, by introducing double and triple glazing, and by reducing infiltration losses.

Heat consumption in buildings

The estimated heating load of a building is usually determined by calculating the heat transmission loss at design outdoor temperature and adding the heat requirements caused by ventilation and infiltration losses. In addition it is common practice to include allowances (safety factors) for an exposed situation, excessive wind, cold radiation from a clear sky to the building radiation from cold surfaces to the interior, intermittent heating, etc. The design outdoor temperature and the allowances will usually be fixed somewhat on the safe side, and as the various climatic factors will not have their extreme values simultaneously, the capacity of the heating system will usually be in excess of the actual requirements.

As the estimated heating load is, as a rule, ascertainable from the heating system calculations, the normal way of estimating the annual energy consumption for the heating of buildings is to multiply the heating load per degree of indoor/outdoor temperature difference by the degree days number of the heating season.

$$E = \frac{H}{t_i - t_o} \cdot D \qquad (1)$$

E = annual energy consumption (kcal)

H = estimated heating load (kcal/h)

$t_i - t_o$ = design indoor/outdoor temperature difference

D = degree days

It seems to be generally accepted that this method of calculation will usually lead to values which are too high. This is not only due to the overdimensioning of the estimated heating load, but also to some other factors which reduce the heat requirements, such as heat gain from solar radiation, lighting, electric appliances, and from the inmates themselves.

From measurements in a great number of residences the annual heat consumption as a function of the estimated heating load, the number of degree days, the type of building and the heating system have been investigated [1], [2] and [3]. The investigations have shown that the average heat consumption can be estimated very closely from the sole transmission loss calculation (i. e. omitting ventilating losses and all safety factors) and the number of degree days. In other words the total ventilation loss will on an average neutralize the sum of the miscellaneous heat gains during the heating season. Thus:

$$E = \frac{T}{t_i - t_o} \cdot D \qquad (2)$$

T = estimated transmission loss kcal/h

The researches in question have shown that special "consumption factors" are also needed when this equation is used. The consumption factor, which is defined as the ratio of the actual heat consumption to the calculated heat consumption depends on the heating system, the type of building and the degree of insulation. The actual heat consumption will be:

$$E = \alpha \cdot \frac{T}{t_i - t_o} \cdot D \qquad (3)$$

α = consumption factor

The heat consumption will normally be relatively greatest with central heating when the indoor temperature is maintained at a high level in the whole house day and night. Central heating in blocks of flats, where the total heating cost is divided equally between the tenants, leads clearly to a tendency to waste heat. Electrically heated dwellings, with heaters in all rooms, show an average heat consumption. Heating by stoves is found to give the smallest consumption, because secondary

Table 1

Average consumption factors — α — with different kinds of buildings and heating systems and different degrees of insulation.

Durchschnittliche Verbrauchsfaktoren bei verschiedenen Arten von Gebäuden und Heizungssystemen und unterschiedlichem Isolationsgrad.

Facteurs de consommation moyens pour différentes sortes de constructions et de systèmes de chauffage, et pour des degrés différents d'isolation.

Type of building Gebäudetyp Type de construction	Central heating Zentralheizung Chauffage central	Electric heating Elektrische Heizung Chauffage électrique	Stove heating Ofenheizung Chauffage par poêles
Bad insulation (k = 0,8 Kcal/m² h °C) Schlechte Isolation (k = 0,8 Kcal/m² h °C) Mauvaise isolation (k = 0,8 Kcal/m² h °C)			
Blocks of flats Wohnblöcke Immeubles d'habitation	1,05	0,85	0,80
Semi-detached houses Reihenhäuser Maisons en rangées échellonnées	1,00	0,80	0,75
Single-family houses Einfamilienhäuser Pavillons	0,90	0,75	0,70
Good insulation (k = 0,3 Kcal/m² h °C) Gute Isolation (k = 0,3 Kcal/m² h °C) Bonne isolation (k = 0,3 Kcal/m² h °C)			
Blocks of flats Wohnblöcke Immeubles d'habitation	1,15	1,00	0,90
Semi-detached houses Reihenhäuser Maisons en rangées échellonnées	1,10	0,95	0,85
Single-family houses Einfamilienhäuser Pavillons	1,00	0,85	0,80

rooms will often be kept at a low temperature, and the temperature of most rooms is permitted to drop considerably during the night.

Buildings where the heat capacity is great in proportion to the area of the exterior surfaces, e. g. blocks of flats, have also proved to use relatively more heat than smaller buildings, e. g. single family residences of light weight structure.

It is found that improvements in insulation have given a saving in the annual heat consumption of about 60—80 % of the calculated reduction. Part of the gain is expected to be a rise of temperature in some of the secondary rooms.

The consumption factors in Norwegian houses located in areas with moderate wind are listed in table 1. In Norway the prices per unit of energy are approximately equal in the three different methods of heating, and consequently the cost of heat will have no influence on the consumption factors.

Table 2

The distribution of losses in a single-family house.

Die Verteilung der Verluste in einem Einfamilienhaus.

Répartition des pertes dans un pavillon.

Description Beschreibung Description			Heat losses Wärmeverluste Pertes de chaleur			
Insulation Isolation Isolation	Glazing Fenster Fenêtres	Infiltration Dichtigkeit Imperméabi-lité à l'air	Walls etc. Wände usw. Murs etc.	Windows Fenster Fenêtres	Infiltration Undich-tigkeit Imperméabi-lité à l'air	Total Insgesamt Total
Bad Schlecht Mauvaise	Single Einfach Simples	Airtight Luftdicht Etanche à l'air	71	27	13	111
Bad Schlecht Mauvaise	Double Doppelt Doubles	Airtight Luftdicht Etanche à l'air	71	16	13	100
Good Gut Bonne	Double Doppelt Doubles	Airtight Luftdicht Etanche à l'air	26	16	13	55
Good Gut Bonne	Triple Dreifach Triples	Airtight Luftdicht Etanche à l'air	26	10	13	49
Bad Schlecht Mauvaise	Single Einfach Simples	Leaky Undicht Non à l'air	71	27	26	124
Bad Schlecht Mauvaise	Double Doppelt Doubles	Leaky Undicht Non à l'air	71	16	26	113
Good Gut Bonne	Double Doppelt Doubles	Leaky Undicht Non à l'air	26	16	26	68
Good Gut Bonne	Triple Dreifach Triples	Leaky Undicht Non à l'air	26	10	26	62

The consumption factors and the effect of insulation must be borne in mind whenever there is contemplated a change of heating system or improved insulation with a view to saving of energy.

In order to get an idea of the relative importance of the different kinds of heat losses, a one-story single-family house and a block of flats are taken as examples. The degree of insulation of exterior walls, ceiling and floor is supposed to be either bad (k = 0,8 kcal/m² h °C) or good (k = 0,3). The glazing is supposed to be single (k = 4,5), double (k = 2,6) or triple (k = 1,7). The weather-tightness of the building is supposed to be good (corresponding to an air change rate per hour of 0,5) or bad (air change rate per hour 1,0). An air change rate of 0,5 is considered to be a minimum with regard to proper ventilation conditions.

Table 3
The distribution of losses in a block of flats.
Die Verteilung der Verluste in einem Wohnblock.
Répartition des pertes dans un immeuble d'habitation à appartements multiples.

Description Beschreibung Description			Heat losses Wärmeverluste Pertes de chaleur			
Insulation Isolation Isolation	Glazing Fenster Fenêtres	Infiltration Dichtigkeit Imperméabilité à l'air	Walls etc. Wände usw. Murs etc.	Windows Fenster Fenêtres	Infiltration Undichtigkeit Imperméabilité à l'air	Total Insgesamt Total
Bad Schlecht Mauvaise	Single Einfach Simples	Airtight Luftdicht Etanche à l'air	45	50	26	121
Bad Schlecht Mauvaise	Double Doppelt Doubles	Airtight Luftdicht Etanche à l'air	45	29	26	100
Good Gut Bonne	Double Doppelt Doubles	Airtight Luftdicht Etanche à l'air	17	29	26	72
Good Gut Bonne	Triple Dreifach Triples	Airtight Luftdicht Etanche à l'air	17	19	26	62
Bad Schlecht Mauvaise	Single Einfach Simples	Leaky Undicht Non à l'air	45	50	52	147
Bad Schlecht Mauvaise	Double Doppelt Doubles	Leaky Undicht Non à l'air	45	29	52	126
Good Gut Bonne	Double Doppelt Doubles	Leaky Undicht Non à l'air	17	29	52	98
Good Gut Bonne	Triple Dreifach Triples	Leaky Undicht Non à l'air	17	19	52	88

The traditional Norwegian home with an insulation corresponding to k = 0,8 with double glazing and an air change rate of 0,5 is considered to have a total heat loss of 100 for both the single family house and the block of flats. The relative heat losses of the other types of construction are given in table 2 and 3.

As the area of exterior walls, floors and ceilings will be comparatively largest in single-family houses, the results of improved insulation will be most pronounced here.

A slight increase of the air infiltration rate may influence the heat loss considerably, and in windy areas it pays well to build air-tight houses.

Improved heat insulation in buildings

During the last 15 years a number of good, heat-insulating constructions have been developed in Scandinavia, which are now practically the only ones used. It is the economical insulating materials, which have made this possible.

The predominant constructions are:

Timber frame houses. The execution of the wall will be seem from Fig. 1a and 1b. The thermal transmittance air to air is less than 0,35 kcal/m² h °C, dependent in part on the choice of cladding materials etc. Extensive investigations have been carried out, which show that when properly made, the wall is in every respect good and durable. When the wall is as well insulated as is the case here, the low heat capacity does not bring any disadvantages, even in the event of intermittent heating. This kind of wall is in Norway practically the only one used in buildings with less than 150 m² built area in one storey or two stories. But the wall is also used in blocks of apartments with concrete floors and loadbearing, interior walls. In this case all external and internal claddings are made of noninflammable materials, while timber framing and all layers of paper are retained.

Wooden joists floor. The wooden joist construction for floor over cellars and roofs will be seen from Fig. 2 (here considerations of sound insulation do not as rule enter). The thermal transmittance air to air is round about 0,3 kcal/m² h °C, dependent somewhat on the different forms of execution. The construction is common in buildings with one storey or two stories, in which the wall described above is used.

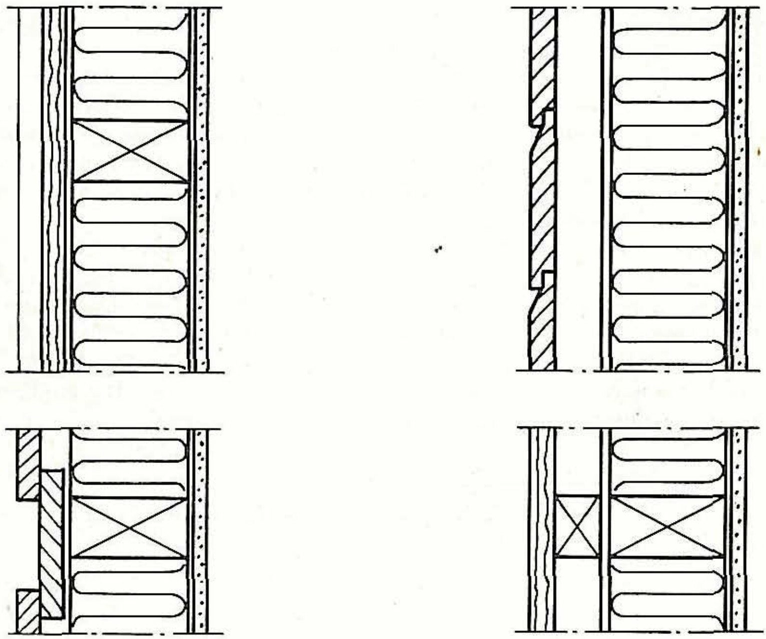
Brick cavity walls. The execution of an ordinary cavity wall will be seen from Fig. 3. The wall has thermal transmittance $k \approx 0,3$ kcal/m² h °C. Extensive experiments show that this wall is very serviceable even in districts with much wind-driven rain.

Light weight concrete walls. The execution is shown in Fig. 4. The thermal transmittance for light weight concrete with density 0,4 kg/dm³ is approximately 0,45 — 0,5 kcal/m² h °C. The thermal conductivity is, however, greatly dependent on the content of moisture and may under unfortunate conditions be much more unfavourable.

Coverings to floors and cellars in non-inflammable materials. Loft floors are as a rule insulated with mineral wool over the concrete cover. The concrete floors over cellars are usually insulated with light weight concrete. These coverings are in some cases also made of reinforced light weight concrete load-bearing constructions.

These constructions can also be made in such a way that they get the same heat insulation as well as the wall constructions described above.

The above-mentioned constructions are now predominant in the Scandinavian countries. The frame constructions and the light concrete constructions involve particularly low costs in the building of the house. All the said constructions in fact form a group with low annual running expenses, when in these are included amortization and interest, upkeep and heating. Under Norwegian conditions these cons-



a b

Fig. 1a and 1b.

The framework usually consists of 2" × 4" posts at intervals of 60 cm. The rest of the wall is built up as follows, from outside to inside: External timber cladding of wood, asbesto cement or something similar, in the case of Alternative b with air space (this is lacking in Alternative a), asphalt impregnated paper, 10 cm impregnated mineral wool cubic weight 30—45 kg/m³, vapourproof paper, inside covering of wood, plaster board or the like.

La charpente se monte généralement en poteaux de 2" × 4" (env. 50 × 100 mm), espacés de 60 cm. Par ailleurs, le mur est construit de la manière suivante, vu de l'extérieur vers l'intérieur: Revêtement extérieur en bois, amiante-ciment ou autre, dans la variante b un espace d'air (inexistant dans la variante a), carton de revêtement ouvert à la diffusion de vapeur, 10 cm de laine minérale imprégnée pesant 30 à 45 kg/m³, barrière de vapeur revêtement intérieur en bois, placoplâtre ou similaire.

Das Fachwerk besteht im allgemeinen aus 2" × 4" Ständern in Abständen von 60 cm. Im übrigen hat die Wand folgenden Aufbau, von aussen nach innen: Aussenverkleidung aus Holz, Asbestzement oder dergleichen, bei Alternative b Luftzwischenraum (fehlt bei Alternative a), Verkleidungspappe, 10 cm imprägnierte Mineralwolle mit Raumgewicht 30—45 kg/m³, diffusionsdichte Pappe, Innenverkleidung aus Holz, Gipsplatten oder dergleichen.

tructions are, with respect to annual costs, in a special favourable position in comparison with other constructions.

The results obtained by using such constructions are shown in Tables 2 and 3. As already stated, improvements in insulation have brought a saving in the annual heat consumption of about 60—80 % of the calculated reduction.

Considerable attention has been devoted to the question of optimum insulation in Scandinavia ever since Axel Eriksson's classical work [4], by Becher in 1950 [5] and other writers in recent years.

The theoretical calculations have had great significance by the fact that they have shown that it pays to insulate very well, but in practice the builder is restricted in the fashioning of the constructions by practical considerations.

The most effective means of introducing good heat insulation is to point to the saving effected and the increased comfort obtained by good heat insulation.

On the part of the authorities builders have been urged to use good insulation, on grounds of national economic benefit. To effect this, good insulation has been rewarded by increased loans and subsidies in connection with the state-aided house-building activity in Norway and Sweden.

It has also signified much that the research institutions in Scandinavia have given great attention to the problems of heat insulation, and have in course of time developed good, highly insulating constructions, which are at the same time economical in building. The building regulations in the Scandinavian countries have long contained provisions respecting heat insulation. A short time ago a proposal was put forward for new joint Scandinavian regulations in this field. The requirements have been made much more stringent. They are given in Table 4.

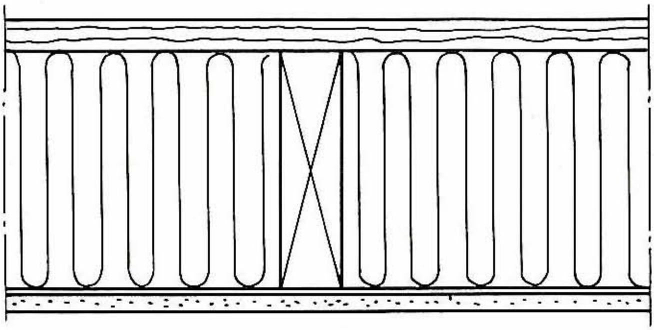


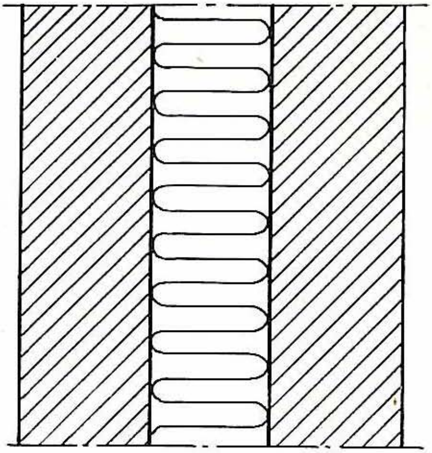
Fig. 2.

The joists usually consist of 8″ beams at intervals of 60 cm. Otherwise the construction is as follows, from above downwards: Floorboards, 20 cm mineral wool, paper (for joists to cellar asphalt impregnated paper, for joists to loft vapour-proof paper), timber cladding, plaster board or the like.

Le plancher se construit généralement en solives de 8″ (env. 200 mm) de haut, espacées de 60 cm. Par ailleurs, la construction est comme suit, vu de haut en bas: Planches, 20 cm de laine minérale, carton (pour plancher contre cave: carton de revêtement; pour séparation contre grenier: carton étanche à la diffusion de vapeur), revêtement en bois, placoplâtre ou similaire.

Die Balkenschicht besteht im allgemeinen aus 8″ hohen Balken in Abständen von 60 cm. Im übrigen ist die Konstruktion wie folgt, von oben nach unten: Fussbodenbretter, 20 cm Mineralwolle, Pappe (für Balkenschicht zum Keller Verkleidungspappe, für Balkenschicht zum Boden diffusionsdichte Pappe), Verkleidung aus Holz, Gipsplatten oder dergleichen.

Fig. 3.



The wall is made up as follows, from outside to inside: 1/2-brick leaf, 10 cm mineralwool, 1/2-brick leaf. The outer and inner leaf are connected by binders of ⌀ 5 mm galvanised steel. They are placed in 50 cm squares. Insulation goes uninterruptedly past covers etc. Openings must be placed at the bottom of the outer leaf, and pasteboard or fittings must be placed over openings to conduct water to the side. Instead of brick use is sometimes made of concrete hollow blocks or light weight concrete blocks.

Le mur se bâtit, de l'extérieur vers l'intérieur, comme suit: paroi ½ brique, 10 cm de laine minérale, paroi ½ brique. Les parois extérieures et intérieures sont reliées par des entretoises de ⌀ 5 mm en acier galvanisé. Celles-ci sont placées en quadrillage de 50 cm. L'isolation est continue, donc sans interruptions aux plafonds ou autre. Des ouvertures doivent être pratiquées à la base de la paroi extérieure. Du carton imprégné ou des garnitures métalliques doivent être posés au-dessus des fenêtres, des portes, etc. pour dévier l'eau vers les côtés. Au lieu des briques ordinaires, on utilise quelquefois des briques creuses en béton, ou des plaques de béton cellulaire.

Die Wand wird wie folgt ausgeführt, von aussen nach innen: 1/2-Stein-Ziegelsteinwand, 10 cm Mineralwolle, 1/2-Stein-Ziegelsteinwand. Die Aussen- und Innenwandfläche sind durch Binder aus galvanisiertem Stahl mit Durchmesser 5 mm verbunden. Diese werden in 50 cm c/c angebracht. Die Isolation geht ununterbrochen an Decken usw. vorbei. Am Fuss der Aussenwandfläche sind Öffnungen anzubringen, und über Öffnungen müssen Pappe oder Beschläge angebracht werden, um Wasser zur Seite ableiten zu können. Statt Ziegelsteinen werden hin und wieder auch Betonhohlsteine oder Lichtbetonplatten verwendet.

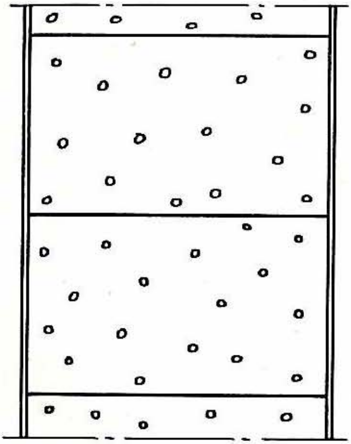


Fig. 4.

Light weight concrete walls are as a rule made of light weight concrete, with a volume weight of 400 kg/m³. The blocks or bars are precisioncut, so that they can be bricked up dry or with adhesive in the joints. External weather protection consist usually of conventional rendering or thin rendering. In particularly exposed places this is not strong enough and must be replaced by an external cladding.

Les murs en parpaings légers sont actuellement bâtis, le plus souvent, en blocs de béton cellulaire d'un poids-volume de 400 kg/m³. Ces parpaings (parfois en éléments longs) sont de coupe précise et peuvent de ce fait s'assembler à sec ou avec une «colle» appropriée dans les jointures. La protection extérieure contre les intempéries est le plus souvent un crépis classique ou un enduit mince. Aux endroits particulièrement exposés ce procédé s'avère insatisfaisant et doit être remplacé par un revêtement extérieur.

Leichtbetonwände werden heute im allgemeinen aus Leichtbeton mit einem Raumgewicht von 400 kg/m³ hergestellt. Die Blöcke (oder Stäbe) sind mit Präzision zugeschnitten, so dass sie trocken oder mit Leim in den Fugen vermauert werden können. Der Aussenwandschutz besteht im allgemeinen aus üblichem Putz oder Dünnputz. An besonders beanspruchten Stellen ist dies zu schlecht, und man muss dort statt dessen Verkleidung verwenden.

Table 4

Joint Scandinavian Building Code. Required thermal transmittance Kcal/m² h °C.
Gemeinsame skandinavische Baupolizeibestimmungen. Verlangte Wärmedurchgangszahl Kcal/m² h °C.
Législation interscandinave sur les constructions. Coefficient de transmission exigé, en Kcal/m² h °C.

Zone	Living room Aufenthaltsräume Chambres de séjour								Cellar Keller Cave
	Wall facing open air Wände zum Freien Mur extérieur			Ceiling facing open air or non-heated room Dach zum Freien oder zu unbeheizten Räumen Toit ou plafond contre espace non chauffé			Floor Fussboden Plancher		Wall facing open air Wände zum Freien Mur extérieur
	Wall made of brick alone Wand aus nur Ziegelsteinen Mur seulement en briques	Other wall with weight exceding 100 kg/m² Andere Wände mit über 100 kg/m² Autre mur, d'un poids supérieur à 100 kg/m²	Wall with weight less than 100 kg/m² Wände mit Gewicht unter 100 kg/m² Mur d'un poids inférieur à 100 kg/m²	Normal requirement Normale Forderung Exigence normale	May be required for a wooden ceiling Kann für Holzdach verlangt werden Peut être exigé pour toit en bois	Facing partially heated room Zu teilweise beheiztem Raum Contre espace partiellement chauffé	Facing non-heated room Zu unbeheiztem Raum Contre espace non chauffé	Facing open air Zum Freien Vers l'extérieur	
1	2	3	4	5	6	7	8	9	10
Zone 1	0,80	0,60	0,40	0,40	0,35	0,60	0,40	0,35	1,10
Zone 2	0,90	0,70	0,40	0,40	0,35	0,60	0,40	0,35	1,40
Zone 3	1,00	0,80	0,50	0,50	0,40	0,70	0,50	0,40	1,70
Zone 4	1,10	0,80	0,50	0,50	0,40	0,70	0,50	0,40	2,00

These provisions are now in force in Sweden and Denmark, and will be laid down in Norway in a short while (in Norway column 2 will be omitted). As will be seen from the table Scandinavia is divided up into 4 climatic zones.

The joint Scandinavian regulations, which apply to dwellings and working rooms which are kept heated, give, further, heat conductivity figures for the materials and the methods of calculation which are to be used.

Ventilation and infiltration

In ordinary dwellings air is withdrawn from kitchen, bath and WC by natural or forced ventilation, while fresh air enters the building by infiltration into all the rooms. The movement of air from the living rooms toward kitchen, bath and WC is considered desirable, in order to avoid the spreading of odours from the latter rooms. Measurements in residences have shown that the actual ventilation rate with a moderate wind will be approximately half an air-change per hr., which in ordinary dwellings will correspond to 100 — 150 m^3 per hr.

In order to be able to control the air change rate, i. e. to reduce infiltration in periods when there is little need for ventilation, and also to avoid excessive infiltration in windy areas, much has been done in Norway to obtain good sealing between the various building elements, and also air-tight windows.

New window constructions are thoroughly tested before use, and are rated according to their air tightness. Consequently windows in Norway have reached a very satisfactory degree of tightness. The infiltration rate of an ordinary window of 1,5 m^2 will normally be less than 5 m^3 per hr. with a wind speed of 10 m per sec. In other localities ordinary window constructions may have an infiltration rate exceeding this value more than 10 times, and field tests in other countries have shown overall air change rates as high as 2 — 3 times the building volume per hour.

Tables 2 and 3 showed that a ventilation rate of 0,5 corresponded to 12 — 42 % of the total heat loss, while a rate of 1,0 corresponded to 21 — 60 %. The elimination of excess ventilation has great significance when it is desired to reduce the energy consumption for heating.

The ventilation heat loss may be reduced by use of "heat exchangers" between the exhaust and supply air. But as the ventilating rate in ordinary dwellings is comparatively low, and as the heat exchanger cannot eliminate the infiltration loss, the advantage of the heat exchanger is considered to be very little.

It should be noted that a building ought to remain at a slight underpressure in order to avoid harmful condensation in the construction caused by low outdoor temperatures. A system of forced air supply, which seems favourable on paper, may in practice prove to be detrimental to the building.

Losses in heating systems

In general, heating systems may be divided into three groups:

1. Electric heating
2. Direct fuel heating
3. Central heating

Electric heating

In the case of electric heating where the heat output can be regulated according to the actual heat demand, the energy losses are negligible. This method is mostly used in electric heating in Norway.

In other countries, where night energy has to be used, exclusively or in as substantial degree, the heat is accumulated in order to serve heating purposes in the day time. This accumulation of heat will always involve some losses.

The cheapest method of storing heat is usually to accumulate it in the structure e. g. in the floor. One of the main objections to this system is that the heat output will be at a maximum in the morning and will diminish gradually during the day, whereas the indoor temperature ought normally to be at a maximum in the afternoon and evening. Sudden changes in the outdoor conditions, such as unexpected sunny days, may lead to overheating and waste of electric power.

A more profitable way or storing the night heat is by means of water containers, from which the heat can be circulated to radiators whenever desired. The heat loss from well-insulated containers of approx. 1000 litres can easily be kept below 200 kcal per hour at full temperature, and as most of this heat can be utilized for basic heating of the building, the actual heat loss will be small.

Night power is also very suitable for the accumulation of domestic hot water.

Direct fuel heating

The efficiency of direct fuel heaters may be as low as 10 % with open fireplaces, which are especially unfavourable in cold weather, because of the great volume of outdoor air which has to be drawn into the room. Although the efficiency of open fireplaces may be as high as 40 — 50 %, when these are properly constructed, heating by open fire can never be justified from the saving point of view of fuel economy.

With the best makes of closed stoves the average efficiency may be as high as 80 %, using most types of fuel, although somewhat lower efficiences are found in practice. With wood and coal fuel, field tests carried out by Norwegian Building Research Institute, have indicated efficiencies from 50 to 80 % with an average of 60 — 70 %, and by the use of coke and the lightest type of fuel oil (kerosine), efficiencies of 60 — 85 % with an average of 75 % are found. Efficiencies above 80 % may be undesirable by use of fuel rich in hydrogen, owing to the risk of harmful condensation in the chimney.

It seems that the best way of reducing heat losses with closed stoves is to replace old and unserviceable stoves with the best makes, to provide suitable kinds of fuel and to instruct people in the art of stoking economically.

Central heating

With central heating several kinds of losses will normally occur, and especially in small oil fuelled systems the resulting efficiency may be very low.

The sulphur content of the oil makes the combustion gasses very corrosive, and in order to avoid corrosion on the heating surfaces, the boiler has to be operated at a temperature of 70 — 80 °C during the heating season.

The high boiler temperature leads to considerable heat loss from the boiler, and during the long periods when pressure burners are not in operation, cold air will be drawn through the furnace and cool the interior of the boiler.

In small single-family houses the estimated heating load may be far less than what corresponds to the smallest makes of high pressure burners, and consequently the boiler has to be larger than is strictly necessary. The burner will only be in operation a small part of the total time, and the constant heat losses from the boiler will grow in proportion.

Field tests carried out on small boilers by Norwegian Buildings Research Institute in the period 1954—59 showed that the heat balance during the heating season will be on an average:

Combustion losses (chimney losses)	22 %
Radiation loss from the boiler	12 %
Draught loss through the boiler	6 %
Pipe losses	4 %
Effective heat	56 %
	100 %

Although some of the heat losses will normally contribute to the heating of the house, the average efficiency of the heating system is considered to be extremely low.

The overall efficiency may be considerably increased by the combined effect of several improvements.

a) The boilers should be better insulated, and the cooling bridges between the boiler itself and the casing should be avoided whenever possible.

b) The ordinary burner proved to be too sensitive towards draught variations, and this point can be improved by increasing the fan pressure of the combustion air.

c) There is need for a smaller burner, which will operate continously at estimated heating load, and thus reduce both the size of the boiler and the length of the off-periods. Both the radiation loss and the interior cooling of the boiler would then be reduced.

d) A continuously regulating type of burner would eliminate the draught loss through the boiler, but available burners of this kind seem to be less reliable then the pressure type burner.

When other types of fuel are used, the heat output may be regulated continuously and the size of the boiler can be chosen to correspond to the estimated heating load.

A considerable part of the losses will be avoided if the boiler can be placed in the heated part of the house, but this will usually require a noiseless burner.

In the case of large central heating plants, which serve a block or blocks of flats, the relative losses are considerably less, and the average overall efficiency is found to be round about 70 — 80 %. In the case of large district-heating plants Swedish investigations indicate overall efficiencies of 80 — 85 % [7], and further reduction of losses seems to be unlikely.

As the large central heating plants can also be fired with crude and cheap fuel, the cost of the heat will be reduced much more than corresponds to the efficiency factor. Experience has shown that district heating is very economical in densely populated areas.

The rise in the standard of living has led to a trend away from direct fuelled stoves towards central heating. (In most countries electric heating is too expensive to be competitive.)

As central heating is found to lead to greater heat consumption than stove heating (Table 1), and as small central heating system usually operate with lower efficiences, a change-over to central heating will result in considerably greater fuel consumption, except where large central heating plants can be installed.

Conclusion

Norwegian experience has shown that a considerable amount of energy can be saved by better insulation of the buildings, by reducing the air change rate caused by ventilation and by improving the efficiency of the heating system. These improvements have also contributed to raise the standard of indoor comfort.

As the outdoor climate in Norway varies considerably from place to place, with design temperature from —6 down to —42 °C and average wind speeds during the heating season of 0,5 to 9,2 m per sec., the climatic conditions in Norway are similar to those in many other European countries.

In Table 5 the degree day numbers of some places in Norway and elsewhere in Europe [6] are given. The definition of degree days varies from country to country, and the official numbers may differ somewhat from those given in the Table, where the following design temperatures are used: Indoor temperature +18 °C. Heating season begins and ends at outdoor temperatures of +10 °C.

Table 5
European degree days.
Gradtage für einige europäische Orte.
«Degree day» («degré jour») pour certaines régions européennes.

Place Ort Région	Degree days Gradtage «Degree days»
Bergen, Norway	3270
Oslo, Norway	4094
Røros, Norway	6292
Tromsø, Norway	5382
Stockholm	4030
Helsinki	4650
Oxford	2500
Hamburg	3020
Paris	2390
Madrid	1540
Venice	1810
Zurich	2970
Vienne	3130
Sofia	2690
Moscow	4840

As the advantage of using energy-saving devices is proportional to the number of degree days, there is reason to suppose that constructions such as are illustrated in Fig. 3 would be beneficial also outside Norway. Likewise one would think that double glazed windows should have a far greater application outside Scandinavia than is the case today.

The means available for attaining reduced heat consumption seem to be:

1. Research institutions which develop good, highly insulating and windproof constructions, and effective heating systems.
2. Encouragement to the use of these by loan institutions.
3. Public building regulations.
4. Information and propaganda activity.

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Summary

In Norway as in other Scandinavian countries considerable saving in energy for heating of buildings has been obtained in particular by good heat insulation. The calculation of annual energy consumption is discussed and compared with field investigations. Figures are presented which show the distribution of the heat loss on walls, windows and infiltrations, in buildings with different heat insulation and tightness.

Examples of good, economical and very efficient heat insulating constructions, developed in Scandinavia, are presented and the results in energy saving stated. Means of introducing good heat insulation are discussed.

The possibilities of saving energy required for heating ventilation air are briefly mentioned, and the losses in the heating system are discussed from the point of view of saving energy.

A substantial reduction of consumption of energy for heating has been archieved in Scandinavia. A similar reduction is possible in countries with milder climatic conditions, whereby reduced annual total expenses, will result.

Résumé

Expériences norvégiennes avec réduction de la consommation d'énergie pour chauffage des immeubles

Par une bonne isolation thermique, on a pu, en Norvège comme dans d'autres pays scandinaves, réduire considérablement la consommation d'énergie pour le chauffage des batiments. Le calcul de la consommation annuelle d'énergie est étudié et comparé avec des enquêtes faites sur le vif. Des chiffres sont présentés qui donnent une idée de la répartition des pertes de chaleur sur les murs, sur les fenêtres et sur la perméabilité à l'air dans des constructions à isolation thermique différente et différemment bien joints.

Des exemples de constructions à isolation thermique de bonne qualité, peu couteuse et très efficace, développés en Scandinavie, sont présentés, et les économies d'énergie sont mentionnées. Différentes méthodes pour la réalisation d'une bonne isolation thermique sont étudiées.

Les possibilités de réduire la consommation de l'énergie absorbée par le chauffage de l'air de ventilation sont brièvement mentionnées, et les pertes dues au système de chauffage sont étudiées en vue, également, d'une économie en consommation d'énergie.

Une réduction importante de la consommation d'énergie-chauffage a été obtenue en Scandinavie. Une réduction similaire est possible dans des pays à climat plus doux, ou l'on pourra, de ce fait, réduire les dépenses totales annuelles.

Zusammenfassung

Norwegische Erfahrungen mit Reduktion des Energieverbrauches für Heizung von Gebäuden

In Norwegen und in anderen skandinavischen Ländern hat man erhebliche Ersparnisse an Energie zum Beheizen von Gebäuden erzielt, und zwar besonders durch Anwendung einer guten Wärmeisolation. Die Berechnung jährlichen Energieverbrauches wird diskutiert und mit Untersuchungen des praktischen Betriebes verglichen. In Zahlen und Tabellen wird die Verteilung der Wärmeverluste auf Wände, Fenster und Undichtigkeiten in Gebäuden mit verschiedener Wärmeisolation und Dichtigkeit dargestellt.

Beispiele guter, billiger und sehr wirksamer Wärmeisolations-Konstruktionen, die in Skandinavien entwickelt wurden, werden beschrieben, und die sich daraus ergebenden Energie-Ersparnisse werden erwähnt. Mittel zur Einführung guter Wärmeisolation werden diskutiert.

Die Möglichkeiten, durch Erwärmen der Ventilationsluft Energie zu sparen, werden kurz erwähnt, und die Verluste im Heizsystem werden vom Standpunkt des Energiesparens aus diskutiert.

In Skandinavien hat man eine wesentliche Herabsetzung des Energieverbrauches für Heizungszwecke erzielt. Eine ähnliche Herabsetzung des Verbrauches lässt sich in Ländern mit milderen klimatischen Verhältnissen erzielen mit dem Ergebnis, dass die jährlichen Gesamtausgaben geringer werden.

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