Energy and Buildings, 15 - 16 (1990/91) 561 - 569

A Simple Computer Model for Estimating the Energy Consumption of Residential Buildings in Different Microclimatic Conditions in Cold Regions

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ABSTRACT

A simple microcomputer model has been developed for planners and designers for estimating the energy consumption of residential buildings in cold climates. The model calculates the energy consumption analytically but roughly takes into account the dynamic energy behaviour of the buildings by exploiting statistically more comprehensive calculations carried out with dynamic models. The microclimatic data needed for the calculations are independent of building types. Should this data not be available, however, it can also be roughly determined according to certain alternatives concerning the building site. The accuracy of the estimations depends on the details in the data. Several data, also including the climatic data, have default values at the beginning. Thus, the model can be used in different phases of the planning process from the first sketches to the final proposal, or at different planning levels from general plans to block plans. Ease in providing the input data has been a special consideration in developing the program.

1. INTRODUCTION

This work is a continuation of an earlier rather extensive research project concerning the building and operating costs of residential areas (ASTA) [1, 2]. One important aspect of the operating costs to consider was to determine how the energy consumption of residential areas depends on planning decisions. In particular, the dependence of the energy consumption of buildings on microclimate was included in the considerations.

However, the results of the project have been, in practice, difficult to apply directly. Thus, it was decided to compress some of the results into a microcomputer model as a handy tool for estimating the energy consumption of buildings in cold climates according to different planning decisions. While the principal users of the model are imagined as being the planners and economists involved in the planning of new residential areas, it can also be applied in the planning of local energy supply. In general, the model is intended for use in situations where estimates of energy consumption are desired at a more general level than the building level, or where the energy properties of buildings should be kept constant for the reconsideration of, for example, the impact of microclimate on energy consumption.

2. CONSIDERING SOME EXISTING METHODS

Before the model was developed, some existing methods were first considered. In general, we did not find any available energy estimation methods especially suitable for the use of planners. The methods considered were in part either too detailed and laborious to use, or too rudimentary, for example, when correctly taking into account the microclimate in the calculations. Some of them also had other inherent weaknesses due to their development principles. Thus, the development of this new model seemed a reasonable proposition.

2.1. Dynamic and static models

Most of the difficulties in the existing methods were encountered in the treatment of solar radiation and free energies. To take them correctly into consideration requires *dynamic models*, because heat transmission is quite a complex phenomenon which depends on the varying internal conditions of a building and the heat capacity of the materials. However, in these models the calculations are much too complicated and time-consuming, needing excessive calculations and computer resources compared to the aimed task of the planned model.

The other possibility is to use *static models* which are based on the use of the degree-days with a correction for the free energies and probably also for the winds. For example, it is a common practice to use the degree-days calculated to +17 °C instead of +20 °C indoor temperature when approximately accounting for all the free energies in the calculations. This method can, however, convey misleading results, especially when the diurnal variations of solar radiation and outdoor temperature are considerable — which is usually the case in the spring.

2.2. Correction for the winds

In addition, the impact of winds has usually been very poorly dealt with in existing methods. Normally it is left for the consideration of the user alone. Here too one needs dynamic models in order to take into account the complicated nature of the airflows inside a building which depend on the different and varying driving forces. One common way to simplify the matter has been to consider the ventilation as being composed separately of a constant ventilation and of an additive infiltration caused by the winds.

In some cases, the impact of winds is treated as a certain reduction in outdoor temperature. However, this method can give quite erroneous results. For one thing, the same wind (excess air infiltration) causes more heat losses during cold weather than during warm weather. Thus, instead of an absolute value the temperature correction should be proportional to the degree-days. Secondly, the correction is not independent of the building type: buildings with high specific conductance need smaller temperature correction than buildings with low specific conductance, allowing for the same effect in infiltration. This means that the correction should also be proportional to the total specific conductances of buildings.

2.3. One index for the climate severity

An interesting approach to the problem of getting a simple and reliable method for taking into account the dynamics in heat transmission, as well as the impact of climate in the energy consumption of buildings, has been to develop one single *climate index* for all different climatic conditions [3]. This makes the treatment of climate in energy estimations very simple. This index is based on extensive calculations with a detailed simulation model of the dynamic energy behaviour of buildings and is thus inherently dynamic.

However, this index has some defects needing improvement from the planner's or designer's point of view. Firstly, the building types employed have been defined according to their thermal properties, not according to the types normally dealt with in planning. Secondly, the index is purely statistical and as such not illustrative of different climate types requiring different attitudes in planning.

Furthermore, although the index is adjusted so as to be the same for all the considered building types under the maximum as well as the minimum climatic conditions used in the calculations, it is not guaranteed to be the same for different buildings existing in intermediate climatic conditions. This is because different building types respond differently to the changes of a certain climatic parameter. Thus, the developed index is not really independent of the building types — which was one of its intentions.

3. THE DEVELOPED ESTIMATION MODEL

3.1. Calculation principles

The model is a generalization of a more accurate calculation model developed for the purposes of the ASTA research [4]. Whereas the original model calculated the energy consumption monthly, this model calculates it only yearly. It also exploits only in statistical terms the results of comprehensive calculations of over 3000 buildings in the ASTA research.

The basic principles of the calculation model were considered to be that:

(1) it should take into account the *dynamic energy behavior* of buildings;

(2) the climatic parameters used in the calculations should be *independent* of building types;

(3) the *accuracy* of the estimations should depend on the accuracy of the input data.

3.1.1. Dynamic energy behaviour of buildings

One important principle in developing the model has been that it should take into account the *dynamic properties of the energy behaviour* of buildings. In this way alone the compound effect of temperature, winds and ventilation system as well as the diurnal variations in temperature and solar radiation can be taken properly into account in the energy calculations. To achieve this as simply as possible, calculation results of more complicated dynamic models have been condensed in the model into *statistical* functions of the impact of winds and free energies on energy consumption.

3.1.2. Climatic parameters independent of building types

The other basic principle of the model is that the *climatic parameters needed for calculations should be totally independent of the building types.* Further, the parameter values should also be quite easily obtained. To achieve these objectives the following climatic parameters were chosen to be used in the model: the *deviation of the degree-days* of the building site from reference degree-days, mean *wind velocity* at the building site and the total *solar irradiation* incident on vertical surfaces of different orientations at the building site. All the parameter values are gross or mean values of the whole calculated time period. For calculating the actual solar heat gain, the model still needs as datum the approximate *main orientation* of the building.

If the previous climatic parameter values are not directly available, they can also be roughly given as simpler data closer to the planning practice. These data are, correspondingly, the situation of the building or building group in the terrain (temperature), the exposure of the site to the winds (wind velocity) and the rough horizon of the building site (solar radiation).

For the actual calculations, the foregoing data are automatically converted by the model into the local degree-days (temperature), mean velocity of the wind incident on the building (wind velocity) and the solar heat gain of the building (solar radiation).

3.1.3. Different accuracy and input levels

Depending on whether the estimations should concern a single identified building or a building group, the program chooses the proper model between two different calculation models:

- model A: rough model at area level (buildings not identified);
- model B: accurate model at building level (identified single buildings).

In model A the buildings can be defined in different generality categories. Thus, the building(s) can be defined, for example, as residential buildings in general, as blocks of flats, small houses, detached houses, service buildings, a school, a shop or an office building.

The accuracy of the estimates also depends on the details in the data. At the most general level, only two kinds of data are needed for the calculations:

(1) category of the building(s);

(2) floor area of the building(s).

The following data have, at the outset, *default* values which are used in a situation where the proper data are not known:

(3) mean floor area of the buildings (only model A);

(4) mean number of storeys of the building(s);

(5) skeleton depth of the building (only model B);

(6) mean floor periphery (only model B);

(7) seasonal degree-days of the building site;

(8) mean seasonal overall wind velocity at the building site;

(9) seasonal total solar radiation incident on vertical surfaces of eight different orientations at the building site;

(10) approximate main orientation of the building.

The input data mainly concern factors which are affected by the planning decisions. However, at the most accurate level when using model B it is also possible to provide data concerning some technical details of the building not considered in town plans. Thus, the model can be used in different phases of the planning process from the first sketches to the final proposal or at different planning levels from general plans to block plans. It can even be used, to some extent, in building design.

3.1.4. Calculation procedure

Both models include several *statistical default values* of different quantity parameters. In model A these are fixed but in model B most of them are changeable. Before calculating the actual heat losses and free energies, model B first calculates the values of several auxiliary parameters. The default values are based on the results of the ASTA research, whereas the auxiliary parameters are partly calculated according to some building types.

For determining the total heat consumption of a building or building group, the model first calculates and sums up *conductive* losses, *ventilation* losses, and the heat consumption used for *warm water supply*. Applying these results, the model then calculates the *free energies* used to cover the heat losses — thus obtaining the total net heat consumption of the building or building group. Concerning the climatic parameters used in the model, conductive losses depend on the degree-days, ventilation losses depend on the degree-days as well as on the wind velocities and free energies depend on the solar radiation.

3.2. Conductive losses

To determine the conductive losses, the model first calculates the total conductance of the building envelope. The calculations are made separately for the basement, the external walls (including windows) and the roof. In model A, the equations of the conductance of walls and roof have been statistically derived for each building category from the results of ASTA research. In model B, the conductances are calculated according to proper U-values and areas of the envelope.

Because the temperature at ground-level does not directly follow the air temperature, the model uses a linear function to obtain proper degree-days for the ground from the given degree-days. Furthermore, because the secondary spaces are usually less heated than the actual living spaces, the degree-days are reduced according to the proportion of the secondary spaces to the total spaces. The conductive losses are calculated in a usual manner according to the determined conductances and degree-days.

3.3. Ventilation losses

In order to calculate the ventilation losses, the model requires as one parameter the mean air exchange factor of the building(s) during the heating period. This is assumed to be composed of a specific (basic) air exchange (naturally or mechanically forced) and of the infiltration caused by winds. The specific air exchange is assumed to be constant during the heating period. This is determined for each building category separately according to the results of ASTA research.

In the ASTA research, the impact of winds on the ventilation was determined quite rigorously by using actual wind statistics and a model which calculates by an iteration method the airflow balance of a building under different pressure and temperature conditions. From calculations with that model using two separate wind *statistics* and different *relative* wind velocities, it was possible to approximately determine the ventilation of different building types as a function of the mean local wind velocity (wind velocity at the building site). The achieved results are presented in Fig. 1.

Second-degree equations were developed from these data for different building types for the purpose of the present model. In model A, the coefficients of the equation were determined according to different building categories alone. In model B, they also depended on the number of storeys and the ventilation system. Because at low velocities the wind does not affect the ventilation, the equations are discontinuous. The accuracy of the equations was not considered very important because, according to the ASTA research, the impact of winds on heat consumption usually turned out to be quite small.

The wind direction was not taken into account — even though its influence can be considerable on certain prevailing wind directions and on certain orientations of the building. These situations, however, occur mostly in open coastal regions and rather less inland. Such cases should in any case require more profound wind analyses, for example by means of wind tunnel tests.

After determining the total air volume of the building(s) according to the statistics of the ASTA results, the model then calculates the ventilation losses in a usual manner using the mean total air exchange rate, the total air

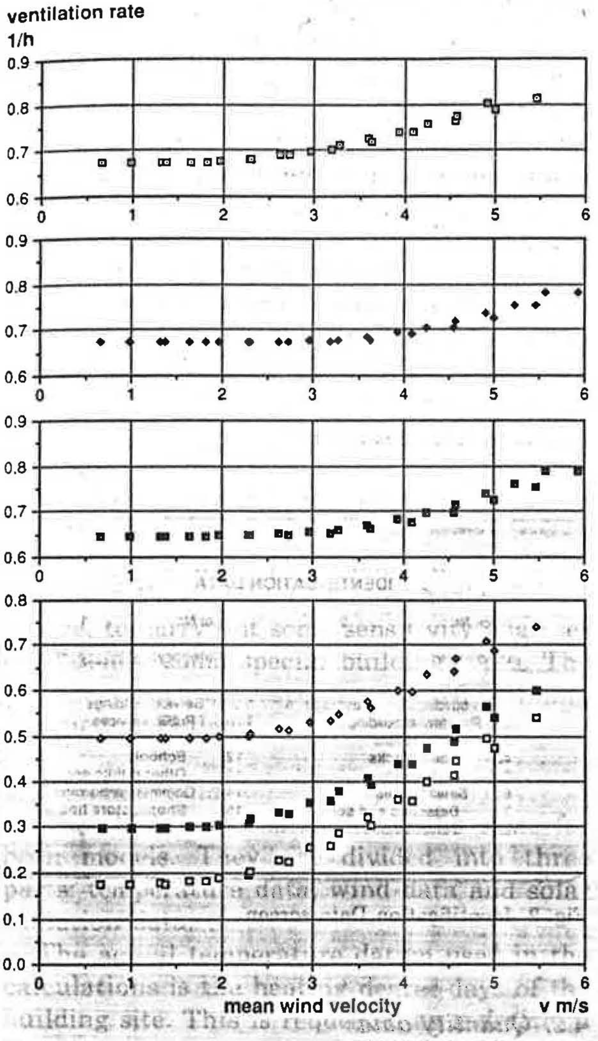


Fig. 1. Average ventilation rate of different building types depending on the mean wind velocity of the heating period: ⊡ service building, mechanical balanced ventilation 0.65 1/h; ◆ tower block, mechanical exhaust ventilation 0.65 1/h; ◘ block of flats, mechanical exhaust ventilation 0.65 1/h; ◇ detached house, mechanical exhaust ventilation 0.5 1/h; ■ detached house, mechanical exhaust ventilation 0.3 1/h; □ detached house, natural ventilation.

volume and the degree-days determined for conductive losses.

3.4. Free energies

Free energies are composed of all the endogenous energies as by-products of the activities inside the buildings as well as of the solar heat gain.

Endogenous energies depend in the model on the building type, the mean size of dwellings and the mean living space per inhabitant. In model A, the endogenous energies are determined according to the statistics of the ASTA results for each building category. In model B they are calculated more rigorously depending on the electricity consumption, the heat generated by persons in the building and the warm water consumption. The endogenous energies are considered in this model to be partly stationary and partly variable during the day.

The solar heat gain depends essentially on the size and orientation of the windows as well as on the amount of the solar radiation incident on the building in general. From these factors only the size of windows is not, in principle, affected by planning decisions. However, this too can be altered in model B. The solar heat gain through windows is determined, by using certain values for the glazing and window sizes, from the data of solar irradiation incident on the vertical surface of eight different orientations at the building site as well as from the main orientation of the building(s). This value is then added to the endogenous energies as a variable energy source to comprise the total of all free energies.

However, the problem is that only a certain part of the free energies can be exploited to cover the heat losses. Solving this problem accurately requires the use of extensive dynamic models in calculations. A quite simple model for the free energies was developed in the ASTA research by first using a comprehensive dynamic calculation model of the energy consumption of buildings for calculating the monthly energy consumption of some *typical* buildings with different climate statistics. From these calculations it was then possible to derive certain simple exploitation functions for the free energies available in different situations [4].

Regarding the present model, the exploitation functions developed in the ASTA research were still further simplified. Because the energy consumption is determined in the model only for the whole heating period, it was possible to reduce the exploitation curves of the ASTA research to single exploitation coefficients depending only on the building type.

In model A the solar energy is simply added to the endogenous energies using these exploitation coefficients. This sum now accounts for the free energies exploited to cover the heat losses during the heating period. In model B the solar energy is first added to the variable endogenous energies. The model then applies the exploitation coefficient to all the variable energies together so as to obtain that part of them which is used to cover the losses. The stationary endogenous energies are assumed to be totally exploited because in a cold climate they do not exceed the heating demand when calculated only for the heating period.

The exploitation rate actually depends on, among other things, the size of windows, the heat capacity of materials, the heating regulation system and the ventilation system. In model B, the default values for the coefficient are based on the ASTA results. However, they can be changed — for example, when considering passive solar buildings or shorter time periods than one heating period. Nevertheless, the model could be improved for these purposes by using, for example, some simplified SLR method [5, 6] for estimating the solar heating factor.

4. USER INTERFACE

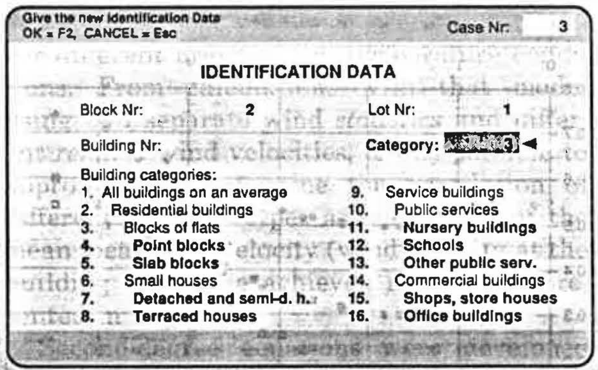
One of the main principles in developing the model has been that it should be so easy to use that it really could be adopted as an integral part of the normal planning process, also by those not familiar with computers. To achieve this the program is, firstly, totally menu-driven and all necessary guidance is always present on the screen. Secondly, the roughest estimates can be obtained with minimal input data: only category and size of the building(s) are obligatory, the rest of the data having default values. The query data have been divided into four groups:

(1) identification data;
(2) quantity data;
(3) special data for model B;
(4) climate data.

4.1. *Identification data*

With identification data, one determines the location of the building(s) and the building type or category. The location data are not necessary. However, it is important for the calculations if the *number* of the building is determined or not. If this is determined, the building is identified as *one building and model B will be used for the calculations.* Otherwise, model A will be used.

The *only necessary* identification datum is the *category of the building(s).* There are 16 different alternatives by which to classify them. The most general category is all buildings by average. The most accurate categories define the basic building types used in ASTA research. If model B has been chosen for calculations (the number of the building being given), the latter categories are actually the only feasible to choose. This condition is automatically checked by the program. The building types and categories are based on the ASTA research. Figure 2 illustrates the Identification Data screen.



```
Give the new Identification Data
OK = F2, CANCEL = Esc                                  Case Nr:     3

                     IDENTIFICATION DATA

   Block Nr:            2              Lot Nr:             1

   Building Nr:                        Category:          3 ◄

   Building categories:
   1.  All buildings on an average      9.   Service buildings
   2.    Residential buildings          10.    Public services
   3.      Blocks of flats              11.      Nursery buildings
   4.        Point blocks               12.      Schools
   5.        Slab blocks                13.      Other public serv.
   6.      Small houses                 14.    Commercial buildings
   7.        Detached and semi-d. h.    15.      Shops, store houses
   8.        Terraced houses            16.      Office buildings
```

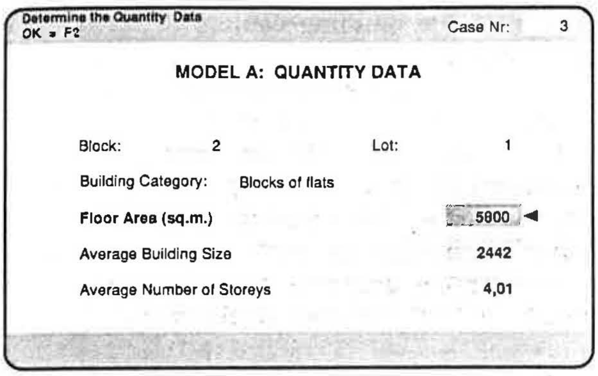
Fig. 2. Identification Data screen.

4.2. *Quantity data*

The only *necessary* quantity datum is the total *floor area* of the building(s). In model A the mean floor area of the buildings (the average building size) and the mean number of storeys have default values determined according to the statistics of the ASTA research. Figure 3 illustrates the Quantity Data screen for model A. Correspondingly, in model B the number of storeys and the skeleton depth have default values according to the same statistics. It is also possible to give the mean floor periphery for model B to determine the envelope of the building more accurately.

4.3. *Special data for model B*

In the building level model, it is even possible to change the default values of parameters which are usually not determined by the planning decisions. However, this data category is conditional and is normally skipped over. The parameters of this category are, for example, the relative envelope area, U-values



Determine the Quantity Data
OK = F2
Case Nr: 3

MODEL A: QUANTITY DATA

Block: 2
Lot: 1
Building Category: Blocks of flats
Floor Area (sq.m.) 5800
Average Building Size 2442
Average Number of Storeys 4,01

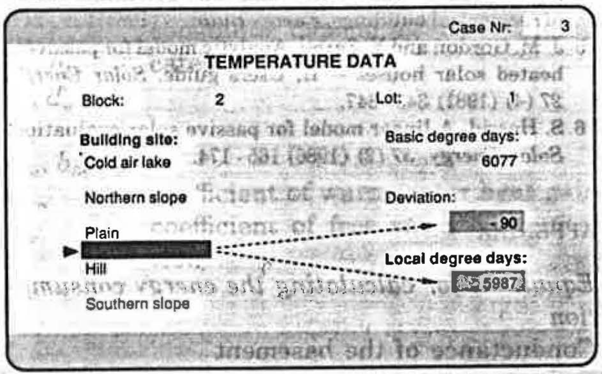
Fig. 3. Quantity Data screen for model A.

of the envelope and windows, window areas, ventilation system, air exchange, storey heights, consumption of warm water, number of dwellings, number of inhabitants, etc. By changing these values, it is possible, for instance, to carry out some sensitivity analyses or consider some special building types. The default values correspond to usual building practice in Finland.

4.4. Climate data

The climatic parameters are the same for both models. They are divided into three parts: temperature data, wind data and solar radiation data.

The actual temperature datum used in the calculations is the heating degree-days of the building site. This is requested as a *deviation from a certain reference degree-days value*. If the deviation is not known, it is also possible to obtain automatically an approximate value for it by choosing the situation of the building or building group in the terrain from given alternatives. The possible alternatives concern height differences, orientation of slopes as well as possible cold air lakes. Figure 4 illustrates the Temperature Data screen.

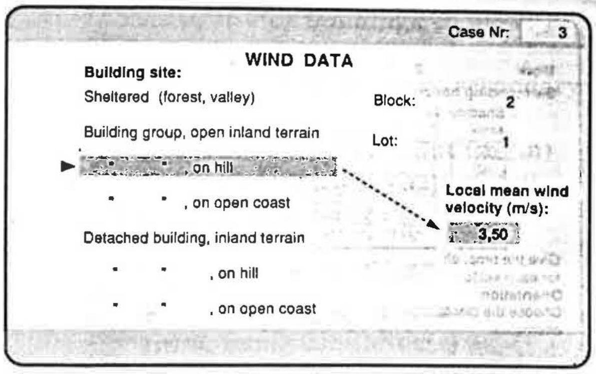


Case Nr: 3

TEMPERATURE DATA

Block: 2
Lot: 1
Building site:
Cold air lake
Northern slope
Plain
Hill
Southern slope
Basic degree days: 6077
Deviation: -90
Local degree days: 5987

Fig. 4. Temperature Data screen.



Case Nr: 3

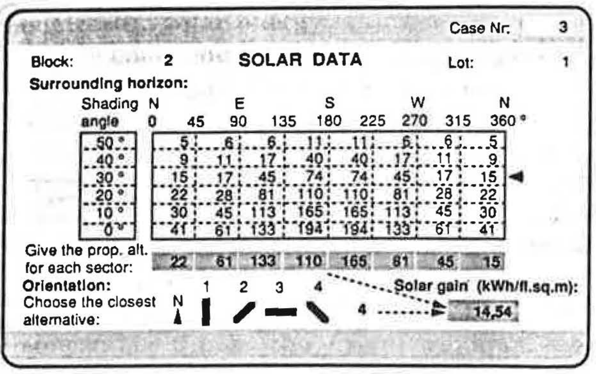
WIND DATA

Building site:
Sheltered (forest, valley)
Building group, open inland terrain
" " , on hill
" " , on open coast
Detached building, inland terrain
" " , on hill
" " , on open coast
Block: 2
Lot: 1
Local mean wind velocity (m/s): 3,50

Fig. 5. Wind Data screen.

The wind datum used for the calculations is the *mean seasonal overall wind velocity on the building site*. In order to obtain this value accurately, a wind tunnel test should be made, because the nature of the airflows around buildings in different situations is very complicated to unravel analytically. However, the impact of winds is usually not very important from the energy point of view. Thus, in most cases it suffices to give only a rough approximation of the windiness of the building site. To do this the user has the option of choosing a proper description of the exposure of the building site to winds from given alternatives. The choice is then interpreted as a local mean wind velocity by the model. Figure 5 illustrates the Wind Data screen. The wind velocities corresponding to the given choices are based on wind statistics of some Finnish locations and the results of wind tunnel tests with scale models made in the ASTA research.

The actual datum needed about solar radiation is the *seasonal total solar heat gain* of the building. In the ASTA research, this was quite rigorously calculated for different parts of the building by using monthly radiation maps of the sky, data about the shading obstructions around the building and the orientation of the building [4]. However, that method is far too laborious for the intended use of this model. Because of this, the solar radiation may be roughly estimated by giving as input data the approximate solar irradiation incident on the vertical surface of eight different orientations at the building site as well as the main orientation of the building itself. If the solar radiation data are not available, it also suffices to roughly determine the approximate horizon of the building site. This corresponds to certain



Case Nr: 3

Block: 2 SOLAR DATA Lot: 1

Surrounding horizon:

Shading N E S W N
angle 0 45 90 135 180 225 270 315 360°

50°	5	6	6	11	11	6	6	5	
40°	9	11	17	40	40	17	11	9	
30°	15	17	45	74	74	45	17	15	◄
20°	22	28	81	110	110	81	28	22	
10°	30	45	113	165	165	113	45	30	
0°	41	61	133	194	194	133	61	41	

Give the prop. alt. for each sector: 22 61 133 110 165 61 45 15

Orientation: 1 2 3 4

Choose the closest alternative: N

Solar gain (kWh/fl.sq.m): 4 14,54

Fig. 6. Solar Data screen.

default radiation values in the model. Figure 6 illustrates the Solar Data screen.

All the correlations between the actual climatic parameters and the corresponding planning parameters are determined according to the ASTA research. They represent ordinary Finnish situations. For special cases the actual climatic data used for calculations should be input directly.

5. CONCLUSIONS

The developed model is intended to be applied in the first place for traditional Finnish buildings in ordinary situations existing within the Finnish terrain and climate. Thus, for example, the energy consumption of cooling is not included in the calculations. However, it is quite possible to extend the model to include other building types as well as to modify it to be applicable in other climate types.

The model is still a prototype and it will be developed further after some experimental use in practice. So far the model has proved to be quite easy to use. However, some parameters used in the calculations still need refining so as to obtain consistent results with both models. The calculation results should also be confirmed by means of comparative calculations using other models. Clearly, the considerations of winds and solar radiation still need improvement. The infiltration functions should be less dependent on certain building types. It might also be possible to roughly take into account the prevailing wind directions and the situation of the building in relation to wind directions. Also, the free energies should be taken into account more flexibly, for example, by using some simplified SLR method. A closer consideration of the solar access to the building could still further improve the method.

At present, the results can be reported only as tabular reports of all or selected building types or special reports concerning individual buildings or building categories. The model will be further developed to also include comparative calculations with altered input data. Moreover, the graphical representation of the results will be included in the model.

ACKNOWLEDGEMENTS

The computer model has been developed in the Laboratory of Urban Planning and Building Design at the Technical Research Centre of Finland. The work was financially supported by the Energy Department of the Ministry of Trade and Industry of Finland. The program is implemented with the PARADOX relation database management program for the IBM PC and its compatibles. PARADOX is a registered trademark of Borland International, Inc. and IBM PC is a registered trademark of International Business Machines Corporation.

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APPENDIX

Equations for calculating the energy consumption

Conductance of the basement

$$G_b = a_g/A_{fm} + b_g/n_{sm} \quad (1)$$

Conductive losses through the basement

$$Q_{cg} = 0.024 \times G_b \times S_g \quad (2)$$

Conductance of the envelope

Model A

$$G_e = a_e + b_e \times n_{sm}/A_{fm} + c_e/n_{sm} + d_e/A_{dw} \quad (3a)$$

Model B

$$G_e = [A_{ew} \times U_{ew} + A_{glz} \times (U_{glz} - U_{ew}) + A_{rf} \times U_{rf}]/A_{fl} \quad (3b)$$

Conductive losses through the envelope

$$Q_{ce} = 0.024 \times G_e \times S_e \quad (4)$$

Mean air exchange factor

$$N = \begin{cases} N_o + a_w \times (v_w - b_w)^2 & v_w > b_w \\ N_o & v_w \leqslant b_w \end{cases} \quad (5)$$

Ventilation losses

$$Q_v = 0.008 \times N \times V_a \times S_e \quad (6)$$

Endogenous free energies (model B)

$$Q_{fi} = Q_p + e_{ww} \times Q_{ww} + 0.75 \times Q_e \quad (7)$$

Stationary free energies (model B)

$$Q_{fs} = 0.5 \times Q_p + e_{ww} \times Q_{ww} + 0.25 \times Q_e \quad (8)$$

Variable free energies (model B)

$$Q_{fv} = Q_{fi} - Q_{fs} + Q_{sg} \times A_{fn} \quad (9)$$

Exploited free energies

Model A

$$Q_{fe} = a_{fe} + b_{fe}/A_{dw} + c_{fe}/A_{ls} + e_{fe} \times Q_{sg} \quad (10a)$$

Model B

$$Q_{fe} = (Q_{fs} + e_{fe} \times Q_{fv})/A_{fl} \quad (10b)$$

Total net energy consumption

$$Q_n = Q_{cg} + Q_{ce} + Q_v + Q_{ww} - Q_{fe} \quad (11)$$

Nomenclature

a_g, b_g $a_e, b_e,$ c_e, d_e a_w a_{fe}, b_{fe}, c_{fe}	constants depending on building category
e_{ww}	coefficient of warm water heat gain
e_{fe}	coefficient of free energy exploitation
A_{fm}	mean size of buildings (floor m^2)
A_{fl}	total floor area (m^2)
A_{fn}	net floor area without secondary spaces (m^2)
A_{ls}	floor area per inhabitant (m^2/in)
A_{dw}	floor area per dwelling (m^2/dw)
A_{ew}	area of external walls (m^2)
A_{rf}	roof area (m^2)
A_{glz}	area of windows (m^2)
n_{sm}	mean number of storeys
V_a	air volume of building(s) (m^3/floor m^2)
U_{ew}	U-value of external walls (without windows) (W/m^2 °C)
U_{rf}	U-value of the roof (W/m^2 °C)
U_{glz}	U-value of windows (W/m^2 °C)
G_b	conductance of the basement (W/°C floor m^2)
G_e	conductance of the envelope (W/°C floor m^2)
N	air exchange rate (1/h)
N_o	specific air exchange rate (1/h)
S_g	degree-days for conduction losses through basement (°Cd)
S_e	effective heating degree-days reduced according to secondary spaces (°Cd)
b_w	lower limit value of the mean wind velocity (m/s)
v_w	mean wind velocity at the building site (at 2/3 height of the building) (m/s)
Q_{cg}	conductive losses through basement (kWh/floor m^2)
Q_{ce}	conductive losses through envelope (kWh/floor m^2)
Q_v	ventilation losses (kWh/floor m^2)
Q_{ww}	energy consumption for warm water supply (kWh/floor m^2 a)
Q_e	electricity consumption (kWh/a)
Q_p	heat load from people (kWh/a)
Q_{fi}	endogenous free energies (kWh/a)
Q_{fs}	stationary free energies (kWh/a)
Q_{fv}	variable free energies (kWh/a)
Q_{fe}	exploited free energies (kWh/floor m^2)
Q_{sg}	solar heat gain (kWh/floor m^2)
Q_n	net energy consumption (kWh/floor m^2)