Chapter 4 A South African Energy Rating Scheme For Residential And Office Buildings

Building energy star rating schemes are seen as effective means of correlating building energy consumption with current design practices. Such a rating scheme can also be applied as a simple means of evaluating building thermal efficiency. Thermal efficiency of a building can be rated according to the maximum heating and cooling loads required for maintaining set temperatures for specific hours of the day. These ratings will however be dependent on climate and building type. An independent rating scheme was consequently developed for South African residential and office buildings.

4.1 INTRODUCTION

Reducing the energy consumption in buildings is one of the major concerns in modern building research and design. Design and retrofit guidelines and regulations are seen as one of the principle means towards eventually realising energy savings goals. Several countries have consequently already implemented such guidelines and regulations [1].

One of the items addressed in these guidelines is the thermal characteristics and therefore thermal performance of the building itself. These guidelines usually stipulate that the building construction must have an equal or lower overall heat transfer coefficient (U value) than a specified value or follows a more descriptive approach that achieves the same effect. However the thermal resistance of the building shell is not the only factor that influences the thermal characteristics of a building. Size, orientation, and glazing area must also be taken into consideration.

The abovementioned factors affecting the thermal characteristics of a building are mostly determined early in the design process. Preliminary design tools should therefore give the design team a simple means of evaluating the efficiency of their design. An energy star rating system is seen as an easy and marketable means of doing this [2,3,4]. Such a rating scheme was developed for rating the thermal efficiency of South African residential and office buildings.

4.2 SIMPLIFIED PRELIMINARY DESIGN RATING SCHEME

The most effective means of evaluating the thermal efficiency of a building is to determine the total annual energy consumption necessary to maintain a specified indoor temperature. This requires calculation and analysis of yearly data for the building. Designers however usually only have access to hot and cold design weather data.

Other drawbacks of this method are the complexity, and the time needed to perform this type of analysis. It is therefore rarely done during the preliminary design stage where its impact will be the highest. A simplified means of analysing building thermal efficiency early in the design process is thus required. For this reason a simplified rating system was developed.

Logic dictates that if the maximum required cooling or heating capacity is lower, then the annual energy consumed by the building to maintain a set indoor temperature will also be lower. The above analysis can thus be simplified from a yearly energy simulation to two quick heating and cooling load calculations, - one for a hot design day, and one for a cold design day.

The heating and cooling loads, normalised to building size, is given a rating compared to that of a suitable reference building. The smaller the heating and cooling load in comparison to that of the reference building the higher the rating of the building. This rating scheme can easily be incorporated into a simple, preliminary thermal design tool for architects.

4.3 REFERENCE BUILDINGS

The building type and application has a strong influence on the typical construction and utilisation of the building. The rating scheme must take this into consideration. Buildings are generally classified as places of assembly, health care facilities, offices, industrial, retail, or residential buildings. Of these, residential and office buildings form the bulk and collectively also have the highest energy savings potential. Therefore this study only focused on obtaining ratings for residential and office buildings.

4.3.1 Residential sector reference buildings

In South Africa, the residential sector can be sub-divided into low-income and medium- to high-income housing sectors. Providing formal low-income housing and subsidised electricity forms an integral part of the South African government's Reconciliation and Development Programme (RDP) [5]. Formal low-income housing is therefore likely to form the bulk of new residences being built. It would be very tempting to minimise the cost of low-income houses without giving any consideration to energy efficiency. However, this would very short-sighted as national energy resources would be wasted.

Low-income houses typically use lower quality building materials and cheaper construction techniques. As a result they will be less thermally efficient. From a cost perspective it is impractical to bring these houses up to a higher standard. These houses should therefore be rated on a separate scale that takes this into account. A separate reference building was thus used for low-income housing.

For the purposes of this study, the 53m^2 house as given in the Agrement booklet no.1 [6] was used as a typical formal low-income house. The 154m^2 house used by Piani [1] for establishing South African energy-savings guidelines, was used as a typical medium-income house. Figures 4.1 and 4.2 present the layout and sketch plan for both of these houses.

Occupancy density for the houses were calculated from

$$\text{Occupants} = 0.111 \times \text{floor area} \tag{4.1}$$

for low-income housing [7], and

$$\text{Occupants} = 0.026 \times \text{floor area} \tag{4.2}$$

for medium-income housing. It is further assumed that all the occupants are at home between 17h00 and 06h00. During the daytime, one third of the occupants were taken to be at home.

These assumptions are in agreement with a South African survey that indicates that the bulk of both these houses have an occupancy density of between 3 and 5 people [8]. Occupancy density and distribution for the reference buildings are shown in Figure 4.3.

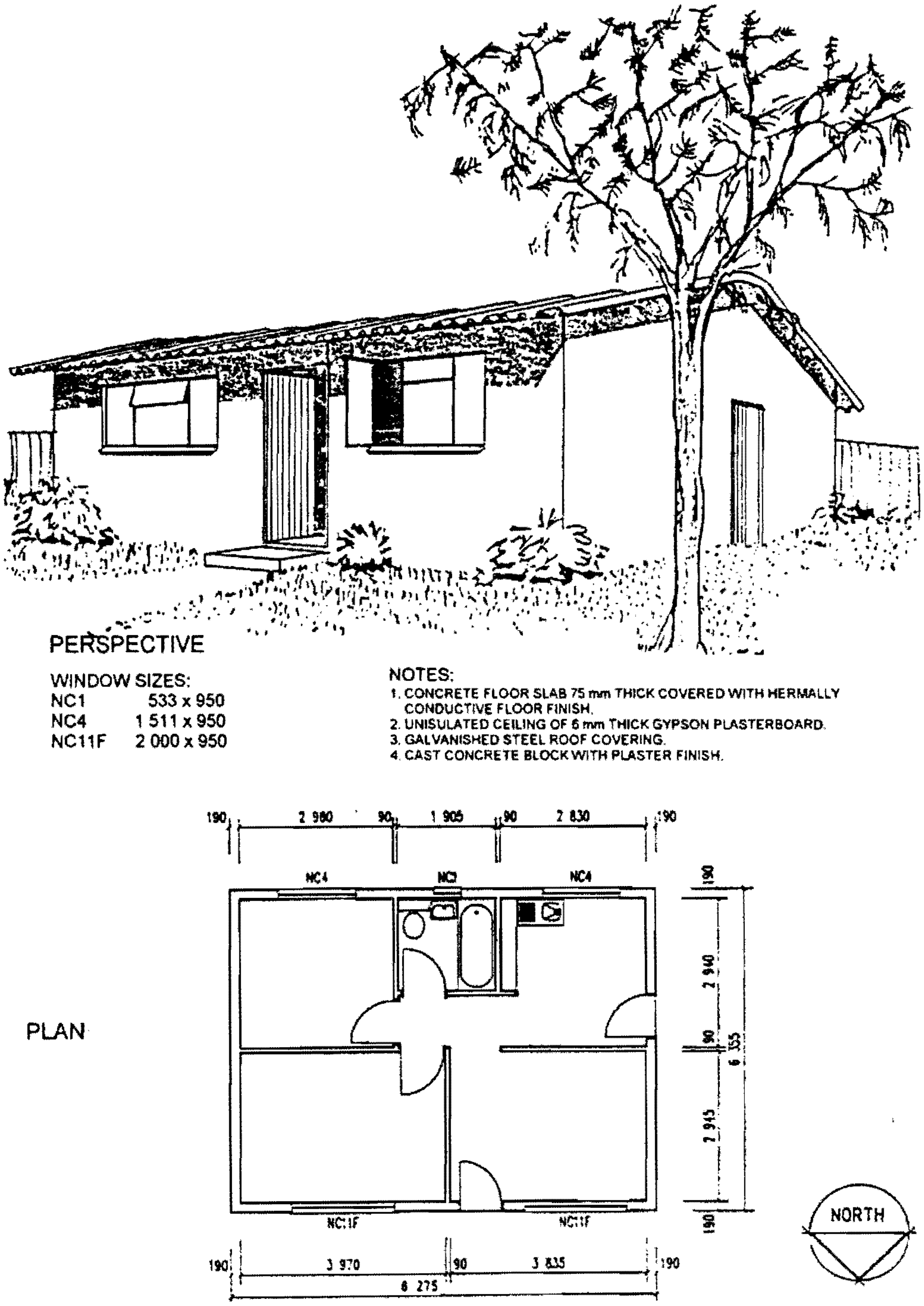

Figure 4.1 – Low-income residential building.

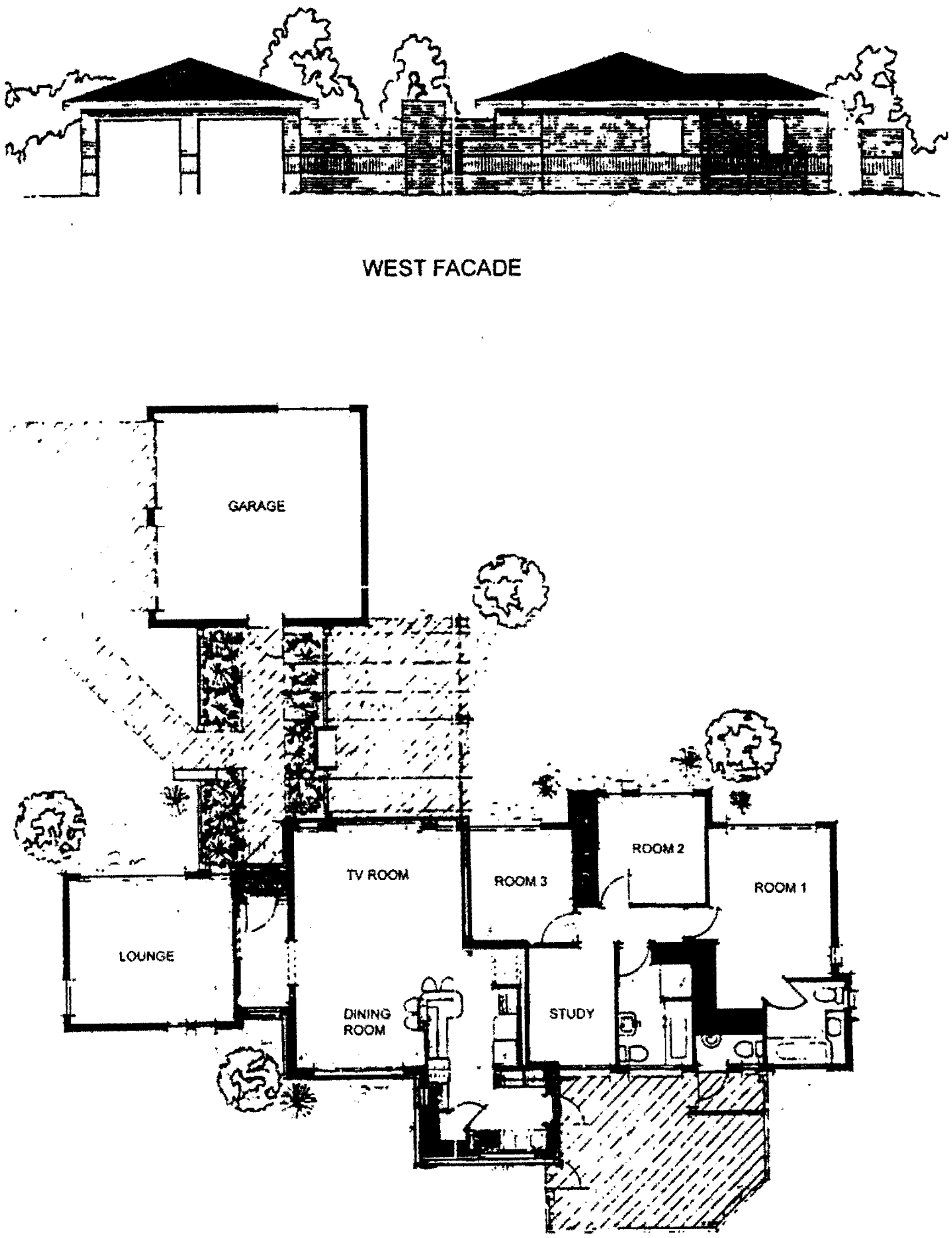

Figure 4.2 – Medium-income residential building.

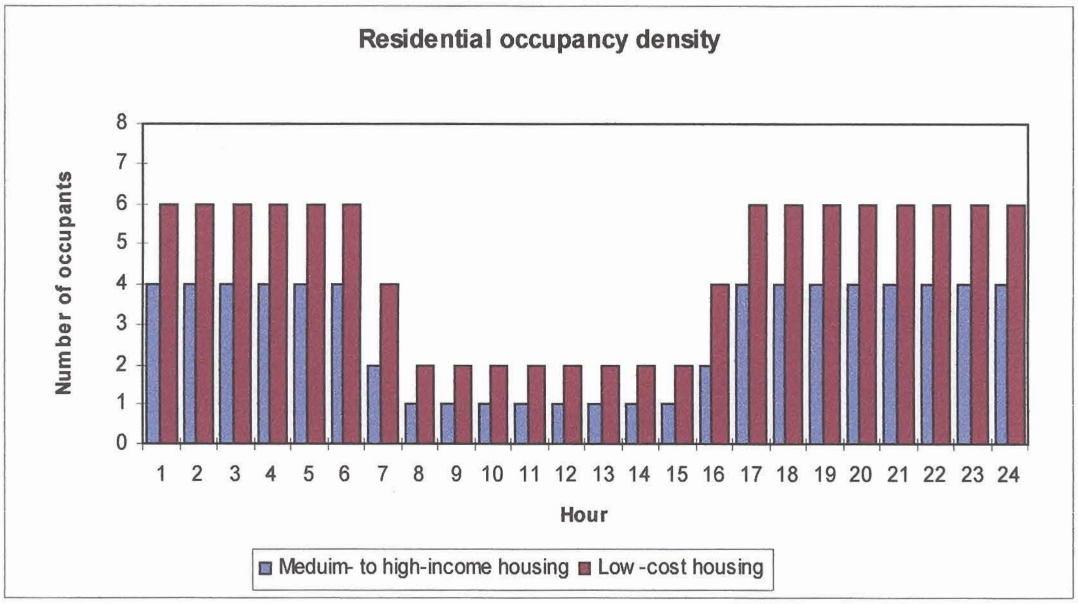

Figure 4.3 - Residential occupancy density.

Preparation of food was taken to be the only other significant contributing factor to the indoor load. Middle-income housing will typically have a higher load due to more appliances being used. Characteristic heat gain values for appliances are given in ASHRAE [9]. Based on the aforementioned assumption, the internal loads were calculated for the low-income and medium- to high-income housing respectively from

$$Internal\ \ load = 7 \times floor\ area\ \text{[W]} \tag{4.3}$$

and

$$Internal\ \ load = 8 \times floor\ area\ \text{[W]}. \tag{4.4}$$

These loads were taken to coincide with the typical time during which food is normally prepared namely, between 06h00 and 07h00, as well as from 17h00 to 20h00.

Most South African residential buildings are unlikely to have any form of mechanical cooling. The rating for these buildings is therefore based only on the heating load. Figure 4.4 represents a typical required winter indoor temperature profile based on comfort requirements. This profile was obtained from a study of 1500 houses [10]. Although the climate conditions for each region vary, the required temperature profile remains unchanged.

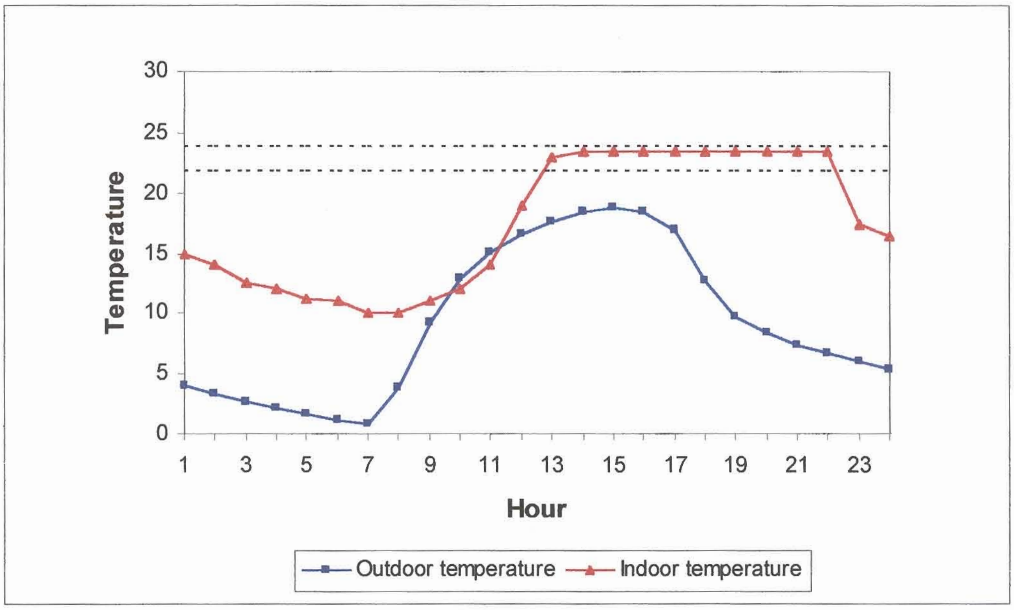

Figure 4.4 – Typical required indoor temperature profile [10].

In practice the suitability of this profile can be debated. In most cases only portions of a house is heated and only in the evening. It does however serve as a basis for comparing different buildings with the same indoor temperature requirements. Furthermore, from a design point of view the maximum heating requirements will occur early in the morning. For the reference buildings it was therefore assumed that heaters would also be used between 05h00 and 08h00 in the morning. Based on general accepted winter comfort norms, the indoor temperature in both low-income and medium-income housing was set to be 22°C.

4.3.2 Commercial sector reference buildings

Piani [1] identified two buildings on which he based his energy savings guidelines for South African commercial buildings. Architects and engineers sanctioned these buildings as good examples of energy efficient building design. One of the buildings serves as reference for passive building design. Passive design is commendable from an energy perspective, but not always practical. The other building applies to structures requiring air-conditioning. This building was consequently used as reference for the commercial sector.

The majority of office buildings are utilised between 08h00 and 18h00. Occupant and interior loads for the reference building were therefore assumed to occur only between these hours. Occupant density, outdoor ventilation and internal loads were calculated from:

$$Occupant\ \ density = 0.1 \times floor\ area\ \ [\mathrm{W}] \tag{4.5}$$

$$Ventilation = 10 \times occupants\ [\mathrm{L/s}] \tag{4.6}$$

$$Internal\ \ Load = 26 \times floor\ area\ \ [\mathrm{W}] \tag{4.7}$$

The internal load is taken to be 40% convective and 60% radiative [11].

Unlike residential buildings most office buildings also have some form of mechanical cooling system. The rating system for office building must therefore take summer as well as winter thermal efficiency into consideration. The required indoor comfort conditions were taken to be 24°C in the summer and 22°C in the winter.

The air-conditioning system however, will typically be operated for one hour before the occupants arrive. System operation for the reference building was thus set from 07h00 to 18h00.

4.4 CLIMATIC REGIONS

Climate plays a major role in the heating and cooling load requirements of the building. A meaningful comparison between buildings can only be made if they are subject to the same climatic environment. Different ratings are thus required for different climatic regions. Wentzel and Hodgson identified fifteen climatic regions for South Africa [12]. These regions are shown in Figure 4.5. An energy rating was consequently calculated for each of these regions.

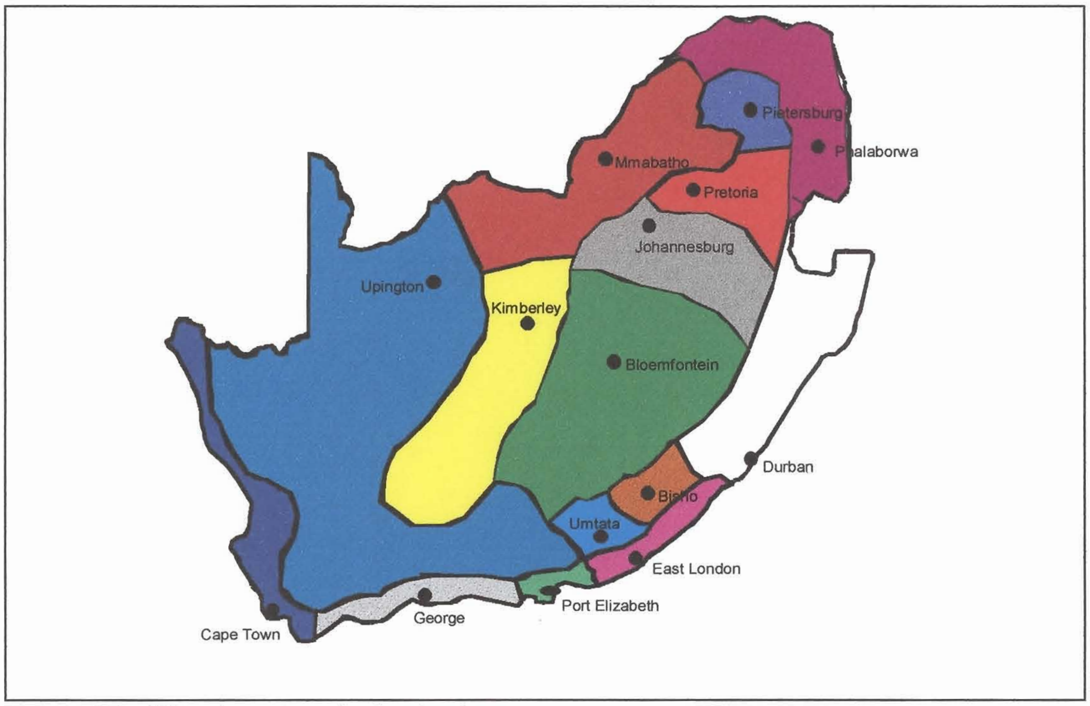

Figure 4.5 - Climatic regions for South Africa.

4.5 SCALING THE ENERGY RATING SCHEME

In order to ensure that it is possible to attain high energy ratings within realistic constraints it is necessary to scale the rating scheme. For this purpose a second set of reference buildings was used. These buildings used for scaling the rating system were chosen to reflect energy efficient buildings.

The residential sector rating scheme was scaled by adding roof insulation to the reference buildings. Studies show that this has a high impact [13,14]. The commercial sector was scaled using the other existing office buildings analysed by Piani [1]. These included buildings that apply expensive design considerations to reduce the load to less energy efficient designs. A suitable range could thus be obtained.

4.6 ENERGY RATING FOR SOUTH AFRICA

A rating scheme consisting of five points was developed using the above reference buildings as basis. The maximum sensible heating and cooling load of the reference buildings and buildings used for scaling were calculated for each of the climatic regions[1]. Latent load is not considered, as it is not influenced by the thermal efficiency of the building shell. These requirements are normalised using floor area. This is done in order to make the rating scheme independent from building size.

For office buildings the average of the normalised cooling and heating load is defined as the building load requirement. Both heating and cooling load are consequently taken into consideration simultaneously. The rating system for the residential sector is however based only on the heating system requirement, as these buildings usually do not have any mechanical cooling equipment.

The minimum requirement for one rating point was set to be the same as that of the reference building. A rating of five is allocated to buildings that have better characteristics than the buildings used to scale the rating scheme. The remaining points are divided evenly between these two extremes. Table 4.1 indicates the rating factor for the various building types and climatic regions of South Africa. To qualify for a particular rating, a building must have a normalised load lower than the first and not smaller than the second indicated numeral.

The rating for a new building is obtained by calculating its heating and cooling requirements under similar load conditions as those of the reference building. This implies that the same assumptions, with reference to occupancy periods and indoor conditions, are made. Internal load and occupancy are however adjusted relative to the building size. This is done using the above equations. A medium-income house, located in Pretoria, with an average heating load requirement smaller than 0.14 kW/m^2 and greater or equal to 0.12 kW/m^2 will for example have a rating of two.

[1] Climate data with a 10% probability was used.

Bisho						
Rating		**1**	**2**	**3**	**4**	**5**
Low cost housing	Load (kW/m² floor area)	0.22–0.20	0.20-0.18	0.18-0.16	0.16-0.14	0.14 >
Medium cost housing	Load (kW/m² floor area)	0.16-0.14	0.14-0.12	0.12-.10	0.10-0.08	0.08 >
Office	Load (W/m² floor area)	72 – 68	68 – 64	64 – 60	60 – 56	56 >
Bloemfontein						
Rating		**1**	**2**	**3**	**4**	**5**
Low cost housing	Load (kW/m² floor area)	0.24-0.22	0.22-0.20	0.20-0.18	0.18-0.16	0.16 >
Medium cost housing	Load (kW/m² floor area)	0.18-0.16	0.16-0.14	0.14-0.12	0.12-0.10	0.10 >
Office	Load (W/m² floor area)	90 – 83	83 – 76	76 – 69	69 – 62	62 >
Cape Town						
Rating		**1**	**2**	**3**	**4**	**5**
Low cost housing	Load (kW/m² floor area)	0.19-0.17	0.17-0.15	0.15-0.13	0.13-0.11	0.11 >
Medium cost housing	Load (kW/m² floor area)	0.14-0.12	0.12-0.10	0.10-0.08	0.08-0.06	0.06 >
Office	Load (W/m² floor area)	59 – 56	56 – 53	53 – 50	50 – 47	47 >
Durban						
Rating		**1**	**2**	**3**	**4**	**5**
Low cost housing	Load (kW/m² floor area)	0.15-0.13	0.13-0.11	0.11-0.09	0.09-0.07	0.07 >
Medium cost housing	Load (kW/m² floor area)	0.11-0.09	0.09-0.07	0.07-0.05	0.05-0.03	0.03 >
Office	Load (W/m² floor area)	47 – 44	44 – 41	41 – 38	38 – 35	35 >
East London						
Rating		**1**	**2**	**3**	**4**	**5**
Low cost housing	Load (kW/m² floor area)	0.12-0.11	0.11-0.10	0.10-0.09	0.09-0.08	0.08 >
Medium cost housing	Load (kW/m² floor area)	0.09-0.08	0.08-0.07	0.07-0.06	0.06-.005	0.05 >
Office	Load (W/m² floor area)	43 – 41	41 – 39	39 – 37	37 – 35	35 >
George						
Rating		**1**	**2**	**3**	**4**	**5**
Low cost housing	Load (kW/m² floor area)	0.18-0.16	0.16-0.14	0.14-0.12	0.12-0.10	0.10 >
Medium cost housing	Load (kW/m² floor area)	0.13-0.11	0.11-0.09	0.09-0.07	0.07-0.05	0.05 >
Office	Load (W/m² floor area)	51 – 48	48 – 45	45 – 42	42 – 39	39 >
Johannesburg						
Rating		**1**	**2**	**3**	**4**	**5**
Low cost housing	Load (kW/m² floor area)	0.21-0.19	0.19-0.17	0.17-0.15	0.15-0.13	0.13 >
Medium cost housing	Load (kW/m² floor area)	0.16-0.14	0.14-0.12	0.12-0.10	0.10-0.08	0.08 >
Office	Load (W/m² floor area)	69 - 64	64 - 59	59 - 54	54 – 49	49 >
Kimberley						
Rating		**1**	**2**	**3**	**4**	**5**
Low income housing	Load (kW/m² floor area)	0.22-0.20	0.20-0.18	0.18-0.16	0.16-0.14	0.14 >
Medium, income housing	Load (kW/m² floor area)	0.17-0.15	0.15-0.13	0.13-0.11	0.11-0.09	0.09 >
Office	Load (W/m² floor area)	102 - 92	92 - 82	82 – 72	72 – 62	62 >
Mmabatho						
Rating		**1**	**2**	**3**	**4**	**5**
Low income housing	Load (kW/m² floor area)	0.22-0.20	0.20-0.18	0.18-0.16	0.16-0.14	0.14 >
Medium, income housing	Load (kW/m² floor area)	0.16-0.14	0.14-0.12	0.12-0.10	0.10-0.08	0.08 >
Office	Load (W/m² floor area)	87 - 80	80 - 73	73 – 66	66 – 59	59 >
Phalaborwa						
Rating		**1**	**2**	**3**	**4**	**5**
Low income housing	Load (kW/m² floor area)	0.12-0.11	0.11-0.10	0.10-0.09	0.09-0.08	0.08 >
Medium, income housing	Load (kW/m² floor area)	0.11-0.09	0.09-0.07	0.07-0.05	0.05-0.03	0.03 >
Office	Load (W/m² floor area)	65 - 61	61 - 57	57 – 53	53 – 49	49 >

Table 4.1 - Energy rating factors for South African residential and office buildings

Pietersburg						
Rating		**1**	**2**	**3**	**4**	**5**
Low income housing	Load (kW/m² floor area)	0.20-0.18	0.18-0.16	0.16-0.14	0.14-0.12	0.12 >
Medium, income housing	Load (kW/m² floor area)	0.14-0.12	0.12-0.10	0.10-0.08	0.08-0.06	0.06 >
Office	Load (W/m² floor area)	66 - 62	62 - 58	58 – 54	54 – 50	50 >
Port Elizabeth						
Rating		**1**	**2**	**3**	**4**	**5**
Low income housing	Load (kW/m² floor area)	0.17-0.15	0.15-0.13	0.13-0.11	0.11-0.09	0.09 >
Medium, income housing	Load (kW/m² floor area)	0.12-0.10	0.10-0.08	0.08-0.06	0.06-0.04	0.04 >
Office	Load (W/m² floor area)	52 – 48	48 - 44	44 – 40	40 – 36	36 >
Pretoria						
Rating		**1**	**2**	**3**	**4**	**5**
Low income housing	Load (kW/m² floor area)	0.21-0.19	0.19-0.17	0.17-0.15	0.15-0.13	0.13 >
Medium, income housing	Load (kW/m² floor area)	0.16-0.14	0.14-0.12	0.12-0.10	0.10-0.08	0.08 >
Office	Load (W/m² floor area)	77 - 71	71 - 65	65 – 59	59 – 53	53 >
Umtata						
Rating		**1**	**2**	**3**	**4**	**5**
Low income housing	Load (kW/m² floor area)	0.22-0.20	0.20-0.18	0.18-0.16	0.16-0.14	0.14 >
Medium, income housing	Load (kW/m² floor area)	0.17-0.15	0.15-0.13	0.13-0.11	0.11-0.09	0.09 >
Office	Load (W/m² floor area)	70 - 66	66 – 62	62 – 58	58 – 54	54 >
Upington						
Rating		**1**	**2**	**3**	**4**	**5**
Low income housing	Load (kW/m² floor area)	0.22-0.20	0.20-0.18	0.18-0.16	0.16-0.14	0.14 >
Medium, income housing	Load (kW/m² floor area)	0.17-0.15	0.15-0.13	0.13-0.11	0.11-0.09	0.09 >
Office	Load (W/m² floor area)	106 - 96	96 - 86	86 – 76	76 – 66	66 >

Table 4.1 - Energy rating factors for South African residential and office buildings (Continued)

4.7 QUALIFICATION OF ASSUMPTIONS AND RATING SCHEME

Various assumptions regarding occupancy periods, indoor loads, ventilation and comfort requirements were made in obtaining the above ratings factors. In practice these assumed values might vary considerably from the actual values. This does however not affect the rating scheme since these parameters do not directly influence the thermal efficiency of a building and the same assumptions are applied to all the buildings being analysed. These factors were only included in the rating scheme in order to maintain a margin of realism

The abovementioned parameters do have a substantial effect on the heating and cooling requirements of a building. As the rating scheme is based on these requirements it was consequently necessary to include these factors so that calculated heating and cooling loads correlates with the total building requirement. An additional benefit of this is that the load calculations necessary for rating the building further provides useful information for the preliminary design of the heating, ventilating and air-conditioning system. To benefit designer in this manner the assumptions are based on general design rule-of-thumb values, comfort requirements and building regulations.

The building load requirements used as basis for this scheme were calculated using NewQuick, a building thermal simulation tool. This program was used as its building model has been extensively verified using actual building data [7,15]. The model therefore has an established track record and credibility. The calculated rating factors can thus be used with confidence. These are important factors if the rating scheme is to be accepted by the design community as a design standard.

4.8 CONCLUSION

A simple energy rating scheme was developed for assessing the thermal efficiency of buildings. It is based on the theory that if the building heating and cooling load is reduced, then the annual energy consumption will also decrease. Detailed energy estimation, required by some rating schemes, can thus be simplified to two design calculations. Using simple thermal analysis software it is easy enough for architects to use it to evaluate their designs.

The rating scheme consists of calculating the design day sensible cooling and heating requirement of the building. This is then compared to that of a reference building. The smaller the required building load in comparison to that of the reference building, the higher the thermal rating of the building. Building features such as size, orientation, glazing area and shading are taken into account with this rating scheme. This method improves on norms that only use the overall heat transfer coefficient as means of evaluating building thermal characteristics.

Housing designers, developers and builders in many other countries have used national or regional energy rating schemes very effectively as marketing tools in distinguishing their product from others with lower performance ratings. This has created a demand by the consumer to purchase a building with a low rating, knowing that he will benefit from lower energy costs and superior indoor climate.

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