

DYNAMIC BUILDING SIMULATIONS FOR THE ESTABLISHMENT OF A MOROCCAN THERMAL REGULATION FOR BUILDINGS

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1 ABSTRACT

Comprehensive dynamic building simulations are used in order to conduct sensitivity analyses on the influence of building shell parameters to the heating and cooling demands of a variety of building types in Morocco. In a first step, five climatic zones are defined covering the range of specific heating and cooling demand combinations of a reference building located in eleven locations throughout Morocco. Afterwards, 22 single parameter variations for each building type and each climate zone are performed and analyzed in such a way, that suitable promising combinations can be defined as well. This procedure is faster and easier to analyze than a multidimensional regression. The results show indeed that the selected combinations may reduce energy demands substantially. This paper explains the procedure and results in detail for one residential type of building and for one typical non-residential building. The major overall results are discussed.

KEYWORDS

building simulation, thermal regulation, Morocco

2 INTRODUCTION AND CURRENT STATE OF KNOWLEDGE

Background of the project is the establishment of a first thermal regulation for buildings in Morocco. The demand for such a regulation becomes obvious when looking at the energy and building sector in Morocco.

The estimated demand on new housing units in 2020 as compared to 2009 is 1,455,000, due to a growth of population, an increased urbanization, and a decrease of the number of people per household [1]. To cover this estimated need on new housing units the Moroccan government created an ambitious building program. Part of this program is the construction

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of up to eleven new cities, the so called “villes nouvelles,” that should accommodate more than 1 million inhabitants out of all social classes. Four projects of these new cities have already been started: Tamansourt, Tamesna, Sahel-Lakhiayta and Chrafate [2].

As a result of the increasing number of housing units and a growing demand on comfort, the demand on energy in the residential and tertiary building sector is growing as well. While in 1990 the residential and tertiary sector had a share of 34% on Morocco's final energy consumption, it rose to 42% in 2004. The consumption of primary energy per habitant rose from 0.34 tons of oil equivalent (TOE) in 2000 to approximately 0.4 TOE in 2005, which corresponds to 12.3 MTOE for Morocco. At the same time, Morocco has to import more than 95% of its primary energy, of which another 95% (as of 2005) are fossil fuels (petroleum products, charcoal and gas) [3].

Compared to other countries in the South and East Mediterranean region, the specific energy consumption in Morocco's residential sector is still very low (40 kWh/m² in 2009). This can be explained by a non-satisfied demand on energy. To satisfy this demand, the consumption on energy will grow further [4].

Therefore, a significant potential to save energy exists. The most efficient way to reduce the future energy-bill is to introduce energy-efficiency measures in new buildings [5].

Most countries in the South and East Mediterranean region have introduced a thermal regulation. The Moroccan government decided as one of the last countries in the region to introduce a thermal regulation for building envelopes. The regulation should contribute to a reduction of energy consumption in the building sector by 1.22 MTOE until 2020 [6].

In order to create the technical details of the thermal regulation, several investigations have to be undertaken. Mandatory measures, which should improve the energy-efficiency of new buildings, must be economically feasible. For example, average social dwellings cost about 250 000 MAD,⁶ additional energetic measures should not exceed investments of 50,000 MAD.

Using detailed parametric studies, the energetic effect of possible measures concerning the building shell are considered. Equipment improvements or replacements are not subject to this investigation. The results may depend on the type of building and its respective usage and load profile as well as on the climatic conditions. The former may lead to a distinction of each one or more residential or non-residential cases, the latter to a regional differentiation in the future building code.

El Andaloussi et. al. quantify the worldwide potential to save energy in the residential sector to 40%. Especially the construction of new buildings offers a high energy saving potential due to the building's long life cycle, the large influence of the thermal building quality, and the low costs for energy-efficiency measures as compared to measures in existing buildings [5].

The internationalization of the building industry in the SEMC (South and East Mediterranean Countries) led to a standardized construction, which replaced traditional building techniques. Where once the building design was adapted to the local climate—thick and massive walls with small openings—today's buildings are made of concrete pillars, braced with a thin layer of vertically perforated bricks and big openings for the windows. Also the ceiling consists of perforated concrete bricks covered with a thin layer of concrete, which does not provide a high heat insulation capacity.

⁶1 MAD (Moroccan Dirham) = 0,12 US-\$ (December 29, 2012)

Several countries of the SEMC therefore tried to counter this development and to introduce a thermal regulation for the building sector. Besides Algeria, Egypt, Turkey, Syria, Lebanon, the Palestinian Territories and Israel, especially Tunisia has developed thermal regulations for the building sector. In 2008, the thermal regulation for office buildings was introduced and from 2009 on another thermal regulation for collective residential buildings became mandatory [5].

The Moroccan government assigned a team of national and international experts to create the technical details for a Moroccan thermal regulation, based on the Tunisian example.

One of the major problems was that little information on the quality of the building envelope and the thermal performance of buildings in the local climate existed. Morocco's climate is very different from the climate of other countries in the region. Even in Morocco itself, the climate is very diverse, from a hot and arid desert climate, to a hot and humid coastal climate, to a cold mountain climate in the Atlas range. Thus one of the first steps was the definition of 6 climate zones, for which parametric simulations of the building envelope were executed. The construction method, used in the simulations, was modified by adding layers between 2 and 8 cm of insulation, without changing the construction technique. This allows improvement to the thermal performance of the building envelope with only little extra costs, so that even the social housing sector can afford to adopt the energy-efficiency measures.

3 METHODOLOGY

Seven building types are being investigated and for this reason modelled using the simulation software TRNSYS 16.1 [7]. TRNSYS is a complete and extensible simulation environment for the transient simulation of systems, including multi-zone buildings. It is used by engineers and researchers around the world to validate new energy concepts, from simple domestic hot water systems to the design and simulation of buildings and their equipment, including control strategies, occupant behaviour, alternative energy systems (wind, solar, photovoltaic, hydrogen systems), etc. One of the key factors in TRNSYS' success over the last 35 years is its open, modular structure. The source code of the kernel as well as the component models is delivered to the end users. This simplifies extending existing models to make them fit the user's specific needs. The multi-zone building model incorporated in TRNSYS was developed in the Mid-Eighties of the last century and allows for the first time a fast correct calculation of heat transfer coupled with thermal storage within the building structure (walls, ceilings, etc.). It is constantly being updated by German developers who took over the building development part due to a large interest in innovative solutions for low energy buildings in Germany [8]. The building model therefore is still one of the most accurate and comprehensive simulation tools worldwide in this respect.

The building types under investigation were selected by the National Agency for the Development of Renewable Energy and Energy Efficiency (ADEREE) [9]:

1. Social housing dwellings, called "Collective Residential",
2. an economic single family house, called "Individual Residential",
3. a simple standard multi-storey residential building, called "Collective Residential Middle Standing",
4. a school building,
5. a hospital building,
6. a public administration building and
7. a hotel.

For selected climatic locations and each of the seven example buildings, the following resulting figures are generated:

- Specific heating energy demand for heating to 20°C room temperature in kWh/(m²a)
- Specific cooling energy demand for cooling to 24°C room temperature in kWh/(m²a)
- Specific heating load in W/m²
- Specific cooling load in W/m²
- Number of hours with room temperatures exceeding 26°C during summer (if not cooled)
- Number of hours with room temperatures lower than 18°C during winter (if not heated)

Single parameter variations of simple building shell measures (insulation, window-to-wall ratio etc.) shall indicate what the future building code should require.

The first building type investigated is the “Collective Residential” housing type according to Figure 1. The modelling of this building type as well as the according individual results given in the subsequent section are presented in detail.

The TRNSYS simulation model is made up of ten thermal zones: two zones for each of the upper floors representing the two apartments, one zone modelling the ground floor as a retail usage, and one zone for the staircase. This 10-zone model has been copied and adapted in such a way that there is one conditioned and one unconditioned building. With this procedure, it is possible to get both heating and cooling energy demands on the one hand and free floating temperature statistics on the other hand. For the base case, the construction design has been selected according to today’s building practice and is documented in Table 1. Table 2 contains characteristic areas and the volume. Using this base case, the building was “placed” into locations with distinct climatic conditions.

FIGURE 1. Floor plans and views of the selected “Collective Residential” housing building.



TABLE 1. Base case building shell design characteristics.

Building Element	Description	Characteristics
Exterior Wall	double-shell construction: 10 cm tile – 10 cm air – 10 cm tile	$U=1.172 \text{ W/(m}^2\text{K)}$
Roof	“Hourdis” construction	$U=2.283 \text{ W/(m}^2\text{K)}$
Floor plate	concrete plus screed	$U=3.947 \text{ W/(m}^2\text{K)}$
WWR	Window-to-Wall Ratio	according to plan
Windows	single glazing, metal frame	$U=5.8 \text{ W/(m}^2\text{K)}$; $g=0.86$
Orientation	Main building orientation	N-S, F1 facing South

TABLE 2. Collective Residential Building Type: characteristic sizes.

		Fassade				Sum
		South	West	North	East	
Gross Area	m²	216.0	54.1	37.8	230.7	538.6
Window area	m²	56.0	9.2	7.5	56.0	128.7
WWR facade	-	26%	17%	20%	24%	24%
WWR total	-	10%	2%	1%	10%	24%
		Building				
Floor area	m²	586.1				
Volume	m³	1735.79				

Table 3 summarizes the simulated interior conditions. The dwellings are used by 5 persons during 17:00 and 07:30, and by 2 persons otherwise. Ventilation rates (including infiltration) are 30 m³/h per person, corresponding to an air change rate of 1 h⁻¹ from 17:00 to 07:30 and 0,4 h⁻¹ from 07:30 to 17:00. The unconditioned case is additionally ventilated during summer at all times when the ambient air temperature is lower than the room air temperature. In these cases, a total air change rate of 4 h⁻¹ is assumed. All internal gains sum up to 2500 kWh per dwelling per year, evenly distributed. External shading (50%) is used during summer (May 15 through September 15) for the complete day (07:30 to 17:00).

TABLE 3. Summary of interior conditions as simulated for the “Collective Residential” building type.

Interior conditions	Week		Week-end	
	7:30 - 17:00	17:00-7:30	7:30 - 17:00	17:00-7:30
Occupancy (persons)	2	5	5	5
Ventilation rate including infiltration (30 m ³ /h per person)	Distributed according occupancy			
Interior gains sum up (2500 kWh/year per dwelling)	Distributed according occupancy			
External shading (by summer) from 15 May to 15 September	50%		50%	
Set point temperature Heating	20 °C			
Set point temperature Cooling	24 °C			

4 CLIMATE ZONES

Climate data for eleven Moroccan locations were used in this investigation. They are partially available in TRNSYS directly or through the Meteonorm software [10].

For two locations, Marrakech and Ifrane, the global horizontal radiation and the ambient temperature are represented in “carpet plots” consisting of 8760 dots representing the 24 hours of the day (vertical direction) for each of the 365 days of the year (horizontal direction). The dot colour is a measure of the value represented in the graph, with the legend on the right hand side. They allow a quick overview on the overall range of values as well as daily and annual fluctuations of irradiation and ambient temperature. The general pattern of the irradiation values does not differ a lot throughout Morocco (see Figure 2 and Figure 4). However,

FIGURE 2. Global horizontal irradiation in Ifrane: hourly values.

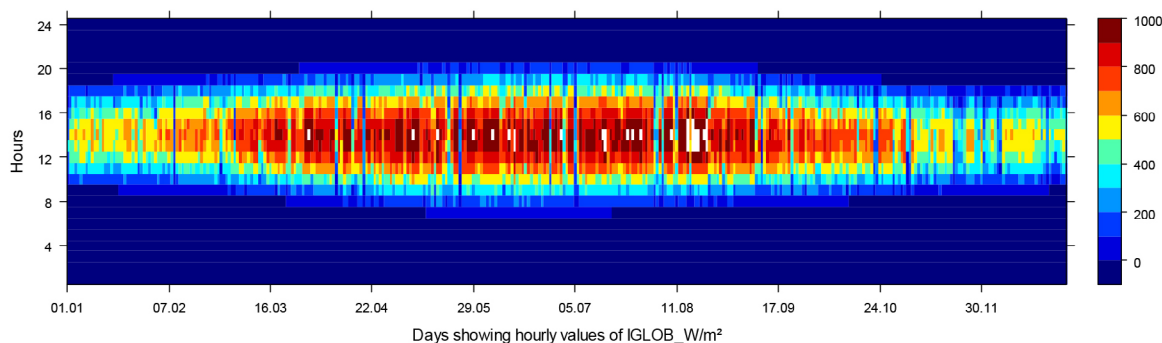


FIGURE 3. Ambient temperatures in Ifrane: hourly values.

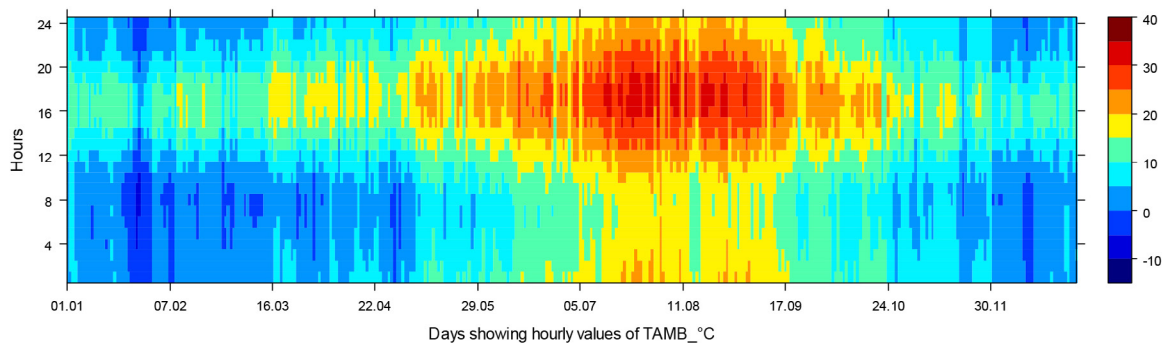


FIGURE 4. Global horizontal irradiation in Marrakech: hourly values.

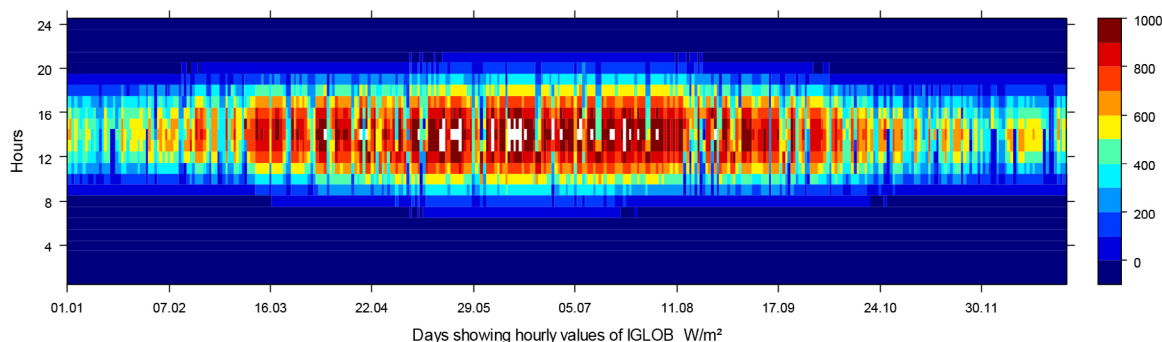
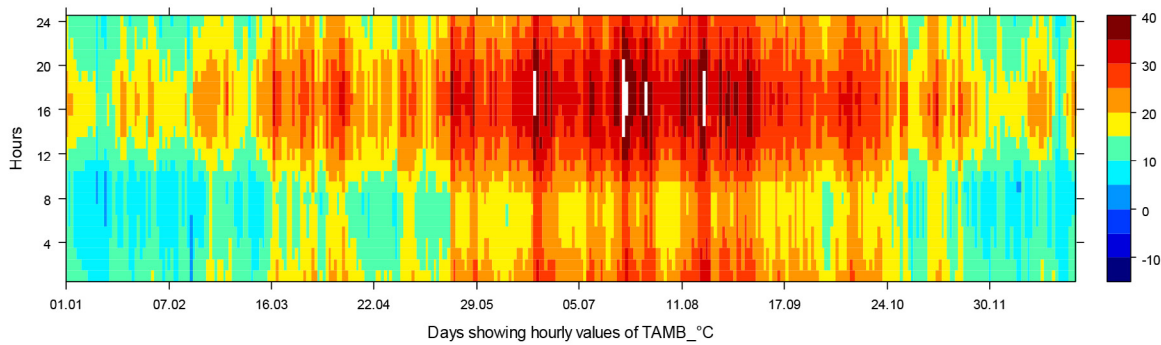


FIGURE 5. Ambient temperatures in Marrakech: hourly values.



the ambient temperatures show obvious variances (Figure 3 and Figure 5). The city of Ifrane is located in the medium-range Atlas mountains and shows clearly a winter season, whereas Marrakech has very hot summer days and nights and still moderately tempered winters.

Eleven locations are investigated using the model of the Collective Residential building type. In Figure 6 the specific cooling energy demand is plotted against the specific heating energy demand at all eleven locations. While, for instance, Ifrane shows a high heating and almost negligible cooling demand, Marrakech needs a lot of cooling but only little heating.

Figure 6 indicates the similarity of respective climate conditions by grouping them accordingly. Another way to look at the same issue is to “turn off” heating and cooling in the simulation and count the hours beyond certain room temperatures considered to limit the comfort region. The results are shown in Figure 7. It is observed that mountainous regions (representative here: Ifrane) may show high heating and almost vanishing cooling demands.

FIGURE 6. Annual specific heating and cooling demand for Building Type 1 in 11 locations.

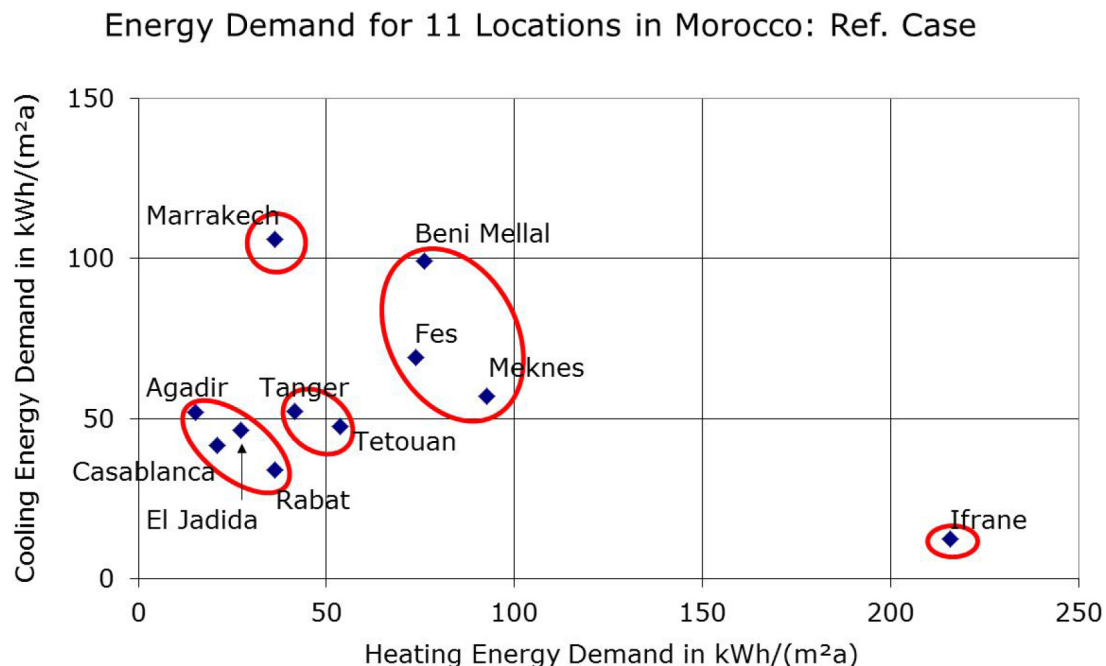


FIGURE 7. Annual number of uncomfortable hours without heating and cooling.

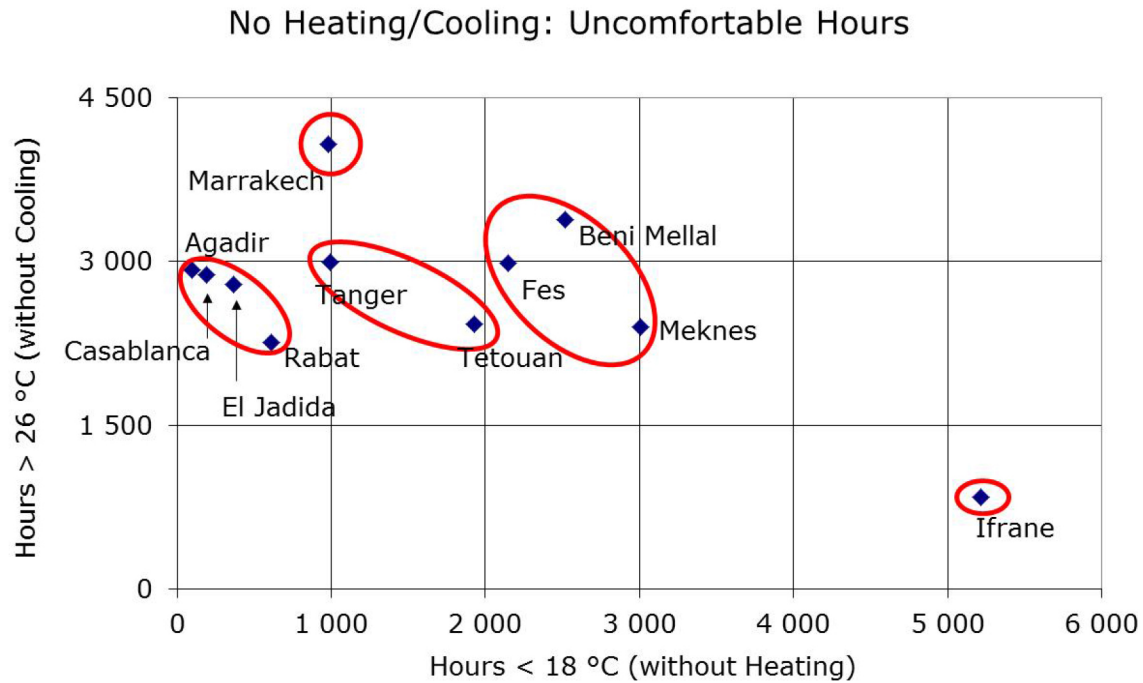


TABLE 4. Representative locations of climatic zones and their qualitative description.

Location	Climatic Characterisation
Agadir	very little heating, moderate cooling demand
Tanger	little heating, moderate cooling demand
Fes	considerable heating and cooling demand
Ifrane	high heating, no cooling demand
Marrakech	very little heating, high cooling demand

In other areas, the cooling demand is considerably higher, in Marrakech, for instance, it is dominant. In a similar way, the observation of the unconditioned case reveals numbers of hours with uncomfortably low or high temperatures, respectively in good accordance with heating/cooling demands in the conditioned cases.

These results determine the basis for defining climatic zones with representative locations as indicated in Table 4 and shown on the map in Figure 8.

5 PARAMETER VARIATIONS

5.1 Collective residential housing dwelling

In a first set of simulation runs, one-dimensional parameter variations are carried out (see Table 5). Note that double glazed windows may not have g-values as high as clear single pane windows; thus, varying the window u-value implies a g-value adjustment.

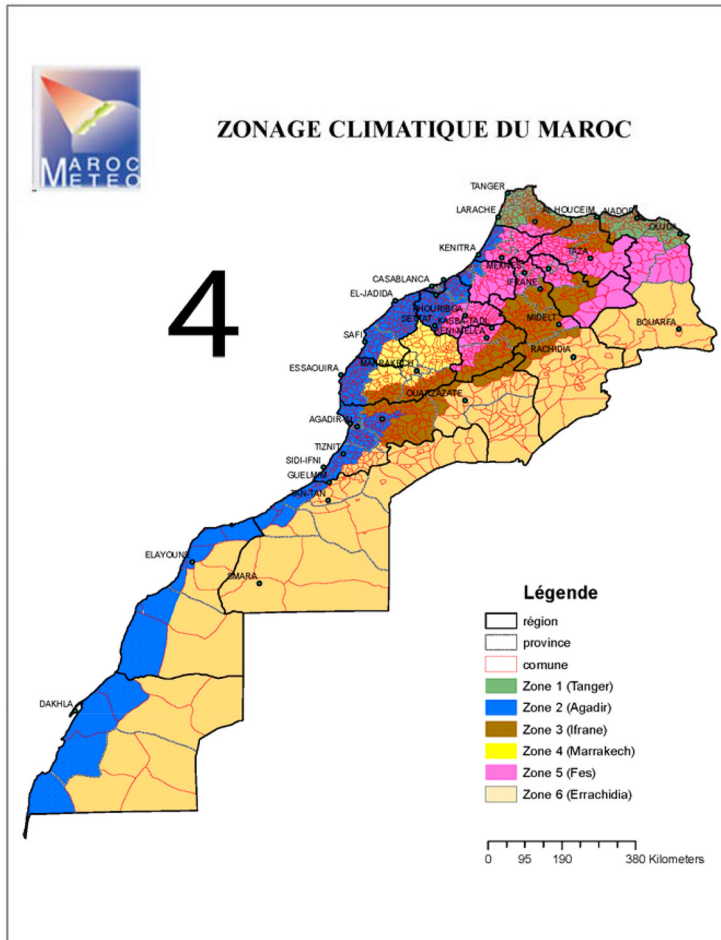


FIGURE 8. Climate Zones in Morocco after evaluation. Note: Zone 6 (Errachidia) was added later and is not subject to the reported investigation.

TABLE 5. 1-dimensional parameter variations.

Object	Parameter	Unit	Values			
Exterior Wall	Insulation thickness (0,04 W/(mk)	cm	2	4	6	
Roof	Insulation thickness (0,04 W/(mk)	cm	4	6	8	
Floor Plate	Insulation thickness (0,04 W/(mk)	cm	2	4	6	
Window	WWR	%	15	25	35	45
	U_Window	W/(m²K)	3,3	2,6	1,9	1,3
	including resp. g-value	-	0,755	0,755	0,624	0,624
	g (reduced by film on single glazing)	-	0,7	0,5	0,3	
Orientation	turn building orientation from S-N to	-	E/W	SW/NE		

Figure 9 through Figure 13 show the results for heating and cooling energy demand for the single parameter variations: starting from the left hand side with the results for the reference case (shaded darker), the effect of three wall, three roof and three floor insulation thicknesses, four Window-to-Wall Ratios (WWR) in %, four window U-values, three g-values and

two orientation variations are shown. These simulations were performed in a first run and the results have been analysed. On the basis of this analysis, several multi-dimensional variations have been carried out. Their results are given as columns at the right hand side. The 9-digit (Table 6) notation follows the code used during the TRNSYS simulations. (Note: a leading “0” is not printed.)

Examples: in Figure 9, the seventh-to-right column representing the results of the first combination is denominated (0)40150000, which translates to 0 cm of wall insulation, 4 cm of roof insulation, 0 cm of floor insulation and a Window-to-Wall Ratio WWR of 15%. Window U- and g-values stay at their reference case values. The last combination, shown on the column at the right end of the graph contains 4, 6 and 0 cm of insulation on walls, roof and floor, respectively, a WWR of 15% and a window with a U-value of 3.3 W/(m²K) and a g-value of 70%.

The following notes discuss the results of this building type:

- The varying climatic conditions can be put in an order of a decreasing cooling to heating demand ratio as follows: Agadir, Marrakech, Tanger, Fes, Ifrane.
- The lowest total energy demand is given for Agadir conditions.
- Agadir shows a negligible heating demand in almost all cases.

TABLE 6. Multi-parameter variation code explanation.

Digit number	meaning
1	Wall insulation thickness in cm
2	Roof insulation thickness in cm
3	Floor insulation thickness in cm
4+5	WWR in %
6+7	Window U-value in W/(m ² K)
8+9	g-value in %

FIGURE 9. Agadir parameter variations of Collective Residential Building Type.

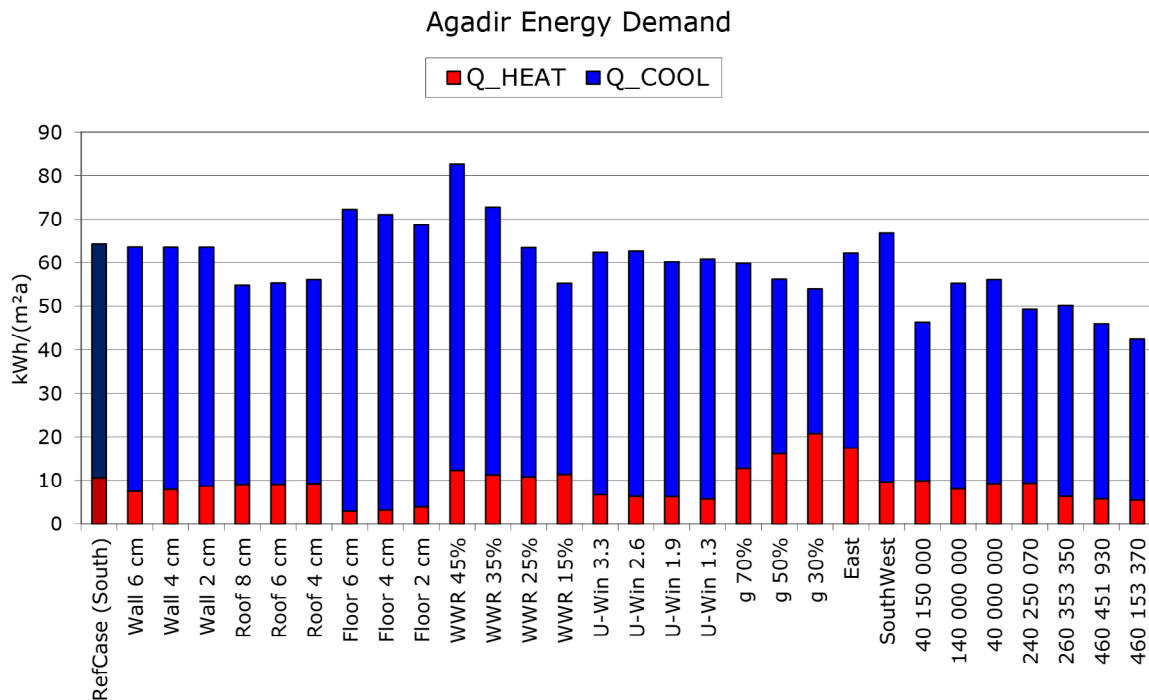


FIGURE 10. Tanger parameter variations of Collective Residential Building Type.

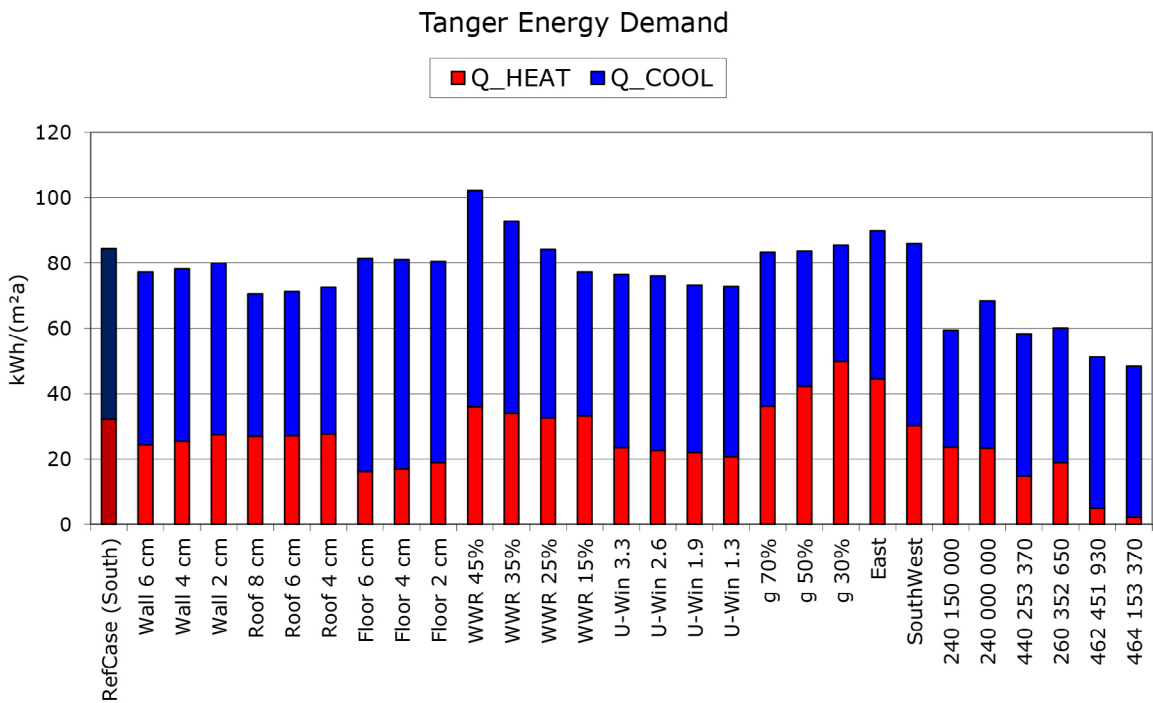


FIGURE 11. Fes parameter variations of Collective Residential Building Type.

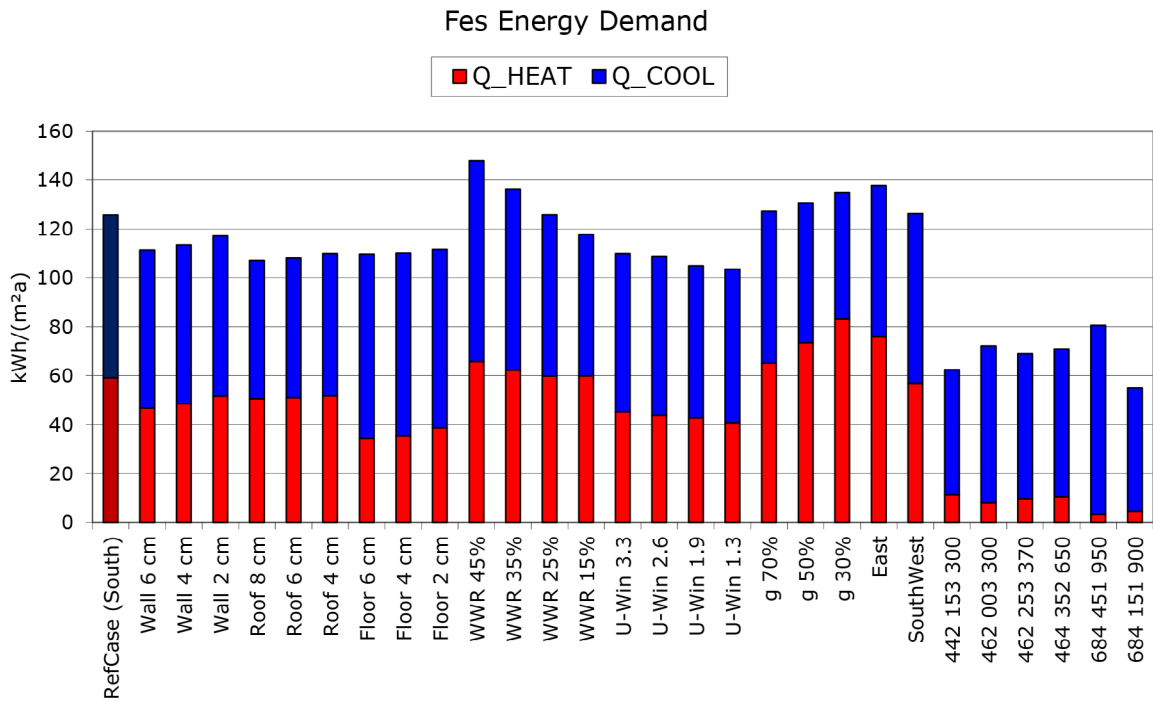
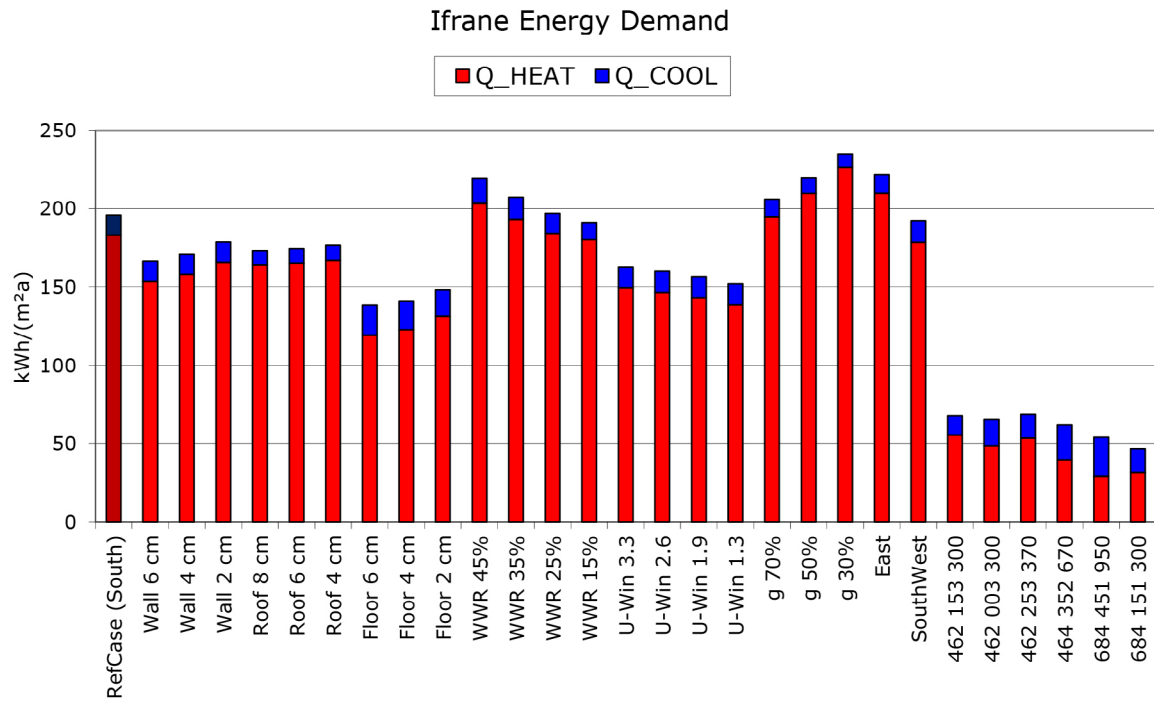
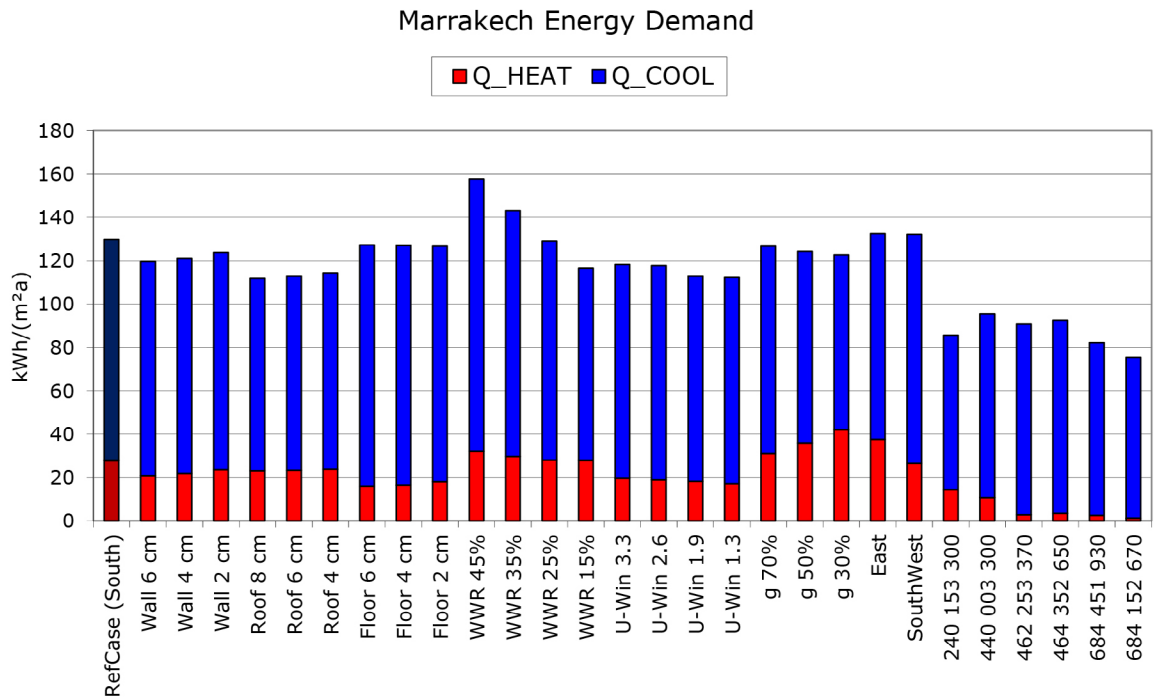


FIGURE 12. Ifrane parameter variations of Collective Residential Building Type.**FIGURE 13.** Marrakech parameter variations of Collective Residential Building Type.

- In contrast to that, Ifrane conditions require only negligible cooling energies.
- Tanger and Fes need both cooling and heating, at least in the single parameter variations.
- It is interesting to observe that by combining several measures in almost all climate conditions the total energy demands may be lowered to the order of magnitude as in the Agadir case, i.e. around 50 kWh/(m²a) or slightly above. Only Marrakech with about 80 kWh/(m²a) for cooling, but virtually no heating, stays a bit higher in its values.
- Large reductions in the heating energy demand are possible, obviously in those regions where heating is predominant: Ifrane and Fes. But also in Tanger and Marrakech, heating may be avoided by applying the correct combinations of measures.
- A suitable window design is crucial for the success of energy saving measures. In all cases, smaller window-to-wall ratios (WWR) improve the situation. In the cooling dominated regions, this is due to limited incident solar radiation. Therefore, smaller g-values also show positive effects. In heating dominated regions, smaller windows lead to higher overall insulation values, since the better insulated walls have larger effects. Here, however, larger g-values are advantageous, since more solar radiation is useful for heating purposes.
- Insulation is of major importance in heating dominated regions. The effect on cooling energy demands is small.
- The insulation of the ground slab (floor insulation) lowers the heating energy demand, but increases the cooling demand. This can be explained by the rather constant temperatures of the ground over the year. During summer, excess heat from the building may be transferred to the ground and thus reduce the cooling load, as long as the floor is not insulated. Insulation keeps the heat inside. Overall, floor insulation is disadvantageous in the Agadir climate; its effect is virtually neutral in Tanger and Marrakech; it is advantageous in Fes and especially in Ifrane.
- The best combinations investigated for this building type lead to the following recommendations: In all climates, the roof should be insulated with at least 6 cm, better 8 cm. The external walls should be insulated with 6 cm or at least 4 cm (Tanger). Only Agadir could cope with a 2 cm insulation. In the Agadir climate, no floor insulation should be applied. Otherwise, not more than 4 cm are recommended. Only the Ifrane climate really benefits from floor insulation. A low WWR is always favourable. A low window U-value is advantageous in Fes and Ifrane. With low WWR, high g-values can be useful for solar gains in winter.

5.2 Public administration building

As a representative of non-residential buildings a “Public Administration Building” according to Figure 14 and Figure 15 is being investigated. The modelling of this building type as well as the according individual results are presented in this section.

For all non-residential building types, it had been agreed to look only at the primary usage rooms. For the Public Administration building, this is a typical office floor layout. Therefore, only a representative section of the building was modelled in the TRNSYS simulation. The model is made up of nine thermal zones: offices from 1st to 4th floor in three orientations (W, S, E) plus the hallway result in four zones; the top floor is geometrically different but analogously modelled; the atrium forms the 9th zone (see Figure 16 and Figure 17). Note that due to the symmetric layout, only half of the building has been modelled.

FIGURE 14. Exemplary ground floor plan (2nd and 3rd floor) of the selected Public Administration building.



FIGURE 15. South view of the Public Administration building.



TABLE 7. Public Administration Building: characteristic sizes.

		Fassade				Sum
		South	West	North	East	
Gross Area	m ²	560.04	283.855	0.0	275.844	1119.7
Window area	m ²	63.80	38.72	0.0	40.0	142.6
Glass-facade	m ²	133.62	97.20	0.0	42.6	273.4
WWR facade	-	35%	48%	0%	30%	37%
WWR total	-	18%	12%	0%	7%	37%
		Building				
Floor area	m ²	1 951.0				
Volume	m ³	5 950.5				

TABLE 8. Summary of interior conditions as simulated for the Public Administration building.**Public Administration Building**

Interior conditions	Week	Weekend	
	8:30 - 16:30		
Occupancy	300 persons in total		
Ventilation rate including infiltration (30 m3/h per person)	Distributed according occupancy		
Interior gains	77 kw in total		
Interior shading (by summer) from 15 May to 15 September	50%	50%	
Set point temperature Heating	20 °C		
Set point temperature Cooling	24 °C		

Summer Holiday : July an August**Holidays : 1 week (first of November) + 1 week (first of January) + 1 week (first of April)**

Table 7 contains characteristic areas and the volume. In Table 8, the interior conditions are summarized. As before, the unconditioned case with free floating temperatures is additionally ventilated during summer at all times when the ambient air temperature is lower than the room air temperature. In these cases, a total air change rate of 4 h⁻¹ is assumed.

The results are presented in the same way as for the residential building type in Figure 18 through Figure 22. The most important results may be summarized as follows:

- The varying climatic conditions can be put in an order of a decreasing cooling to heating demand ratio as follows: Agadir, Marrakech, Tanger, Fes, Ifrane.
- Cooling is predominant, except for Ifrane conditions.
- Heating is negligible in all cases under Marrakech and Agadir conditions.
- Tanger and Fes need both cooling and heating in most of the single parameter variations.
- All multiply optimized cases show no or negligible heating demand, including Ifrane.

FIGURE 18. Agadir parameter variations of the Public Administration Building.

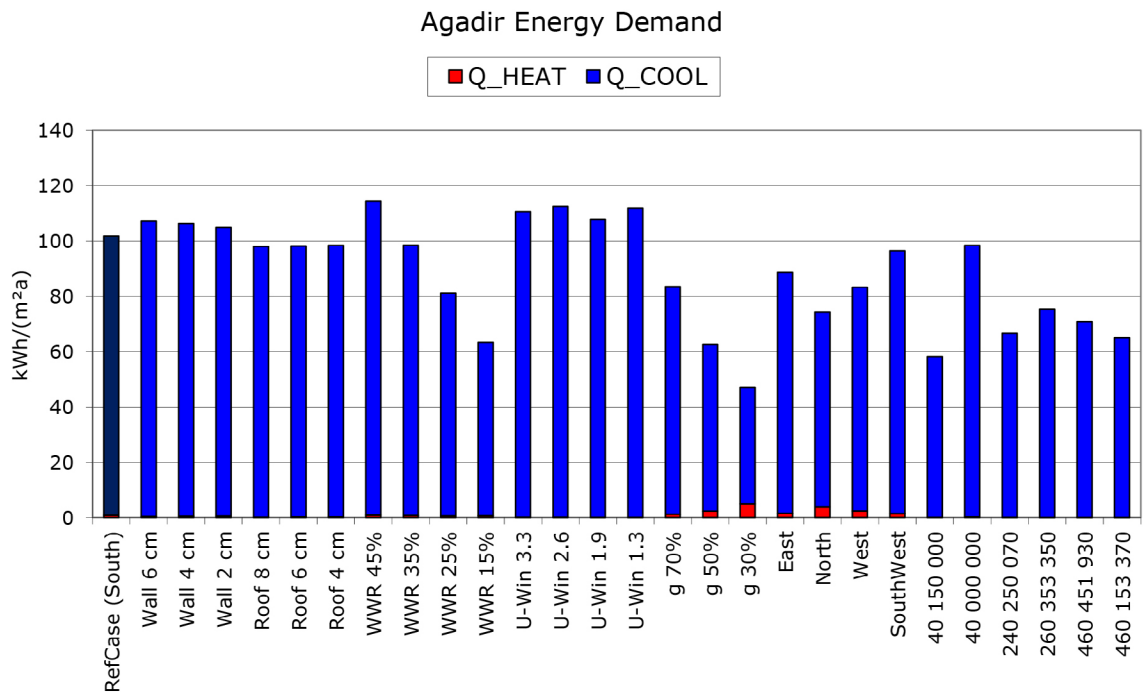


FIGURE 19. Tanger parameter variations of the Public Administration Building.

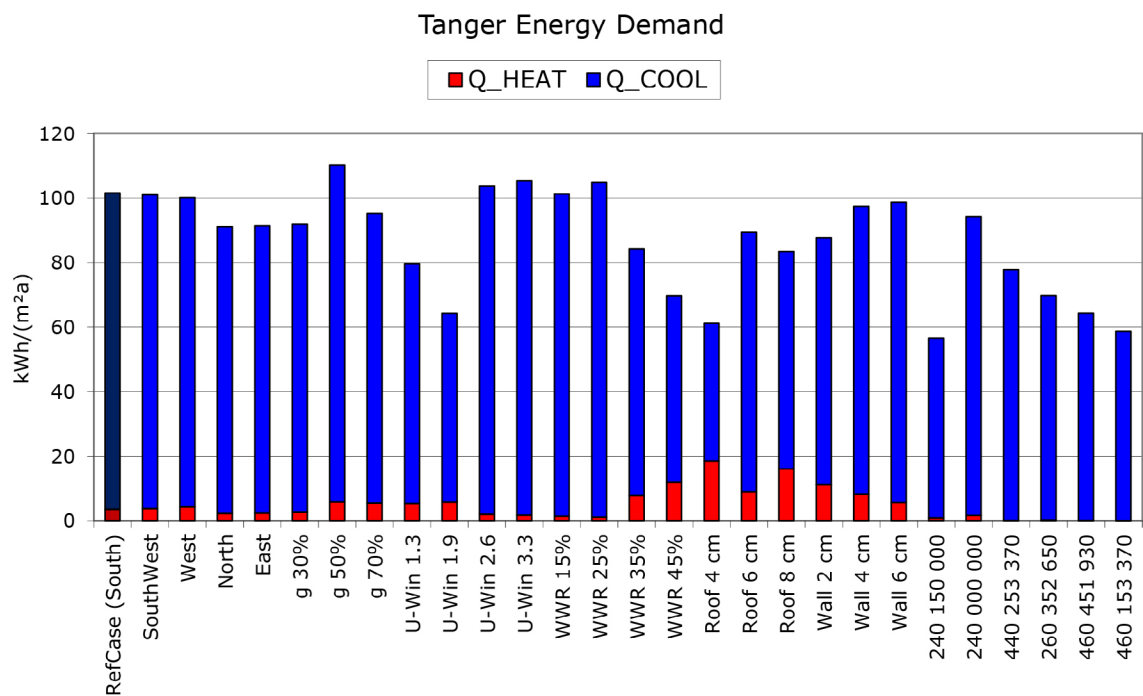


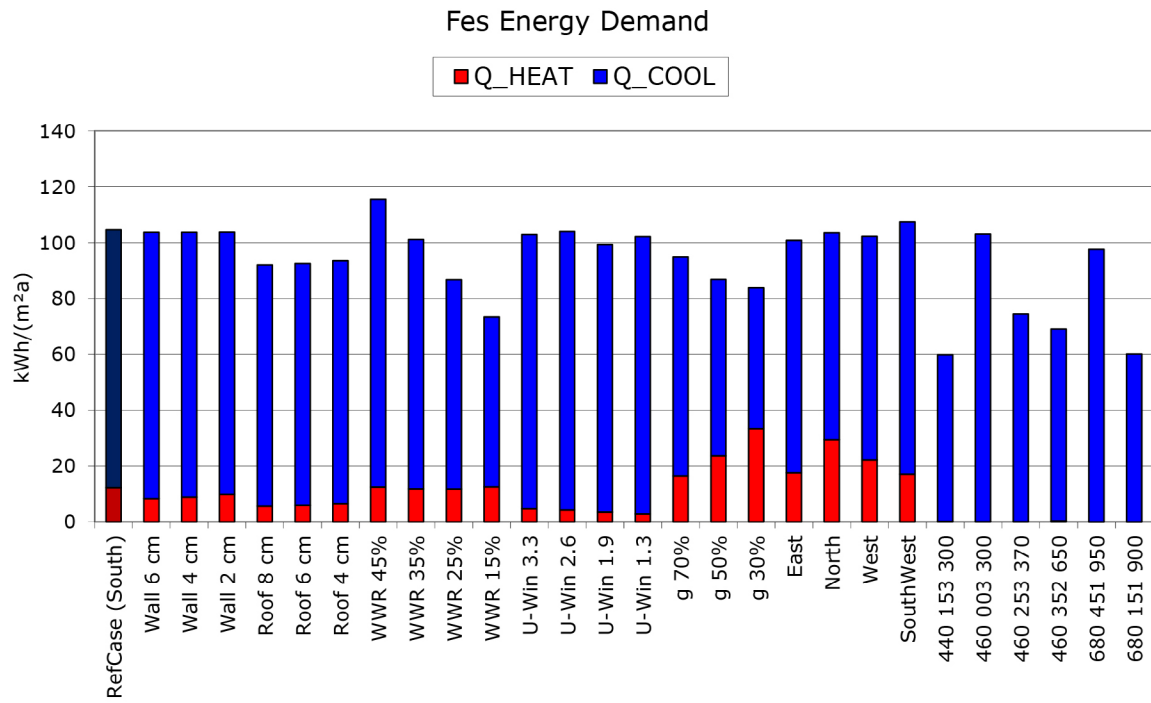
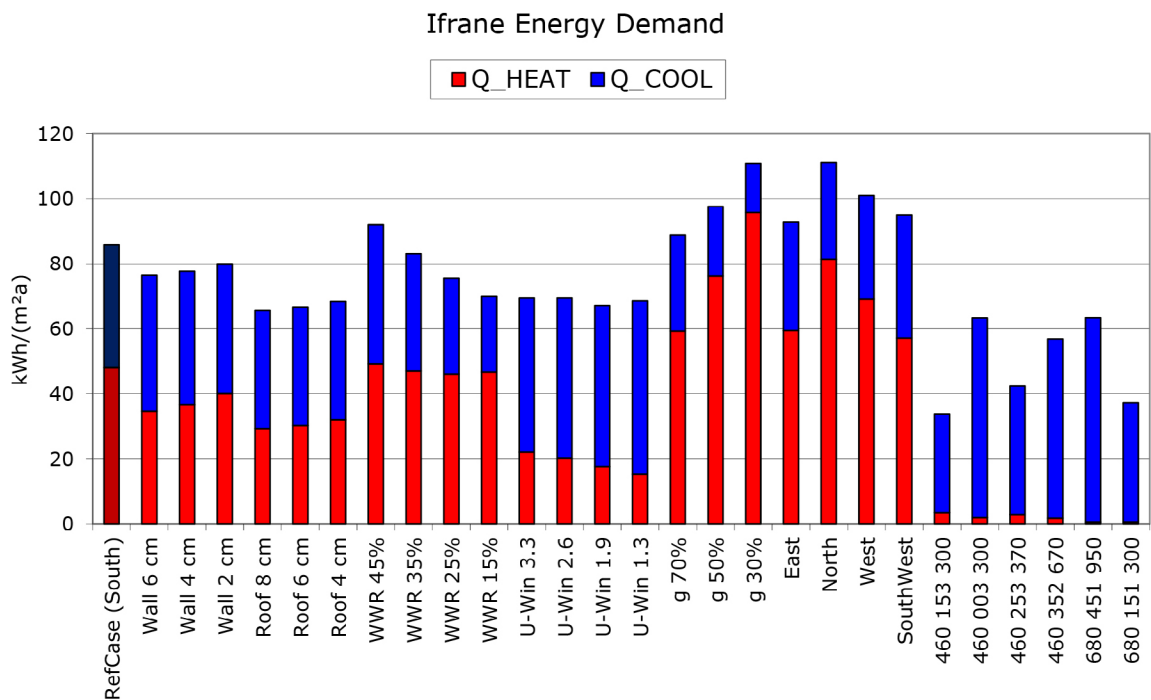
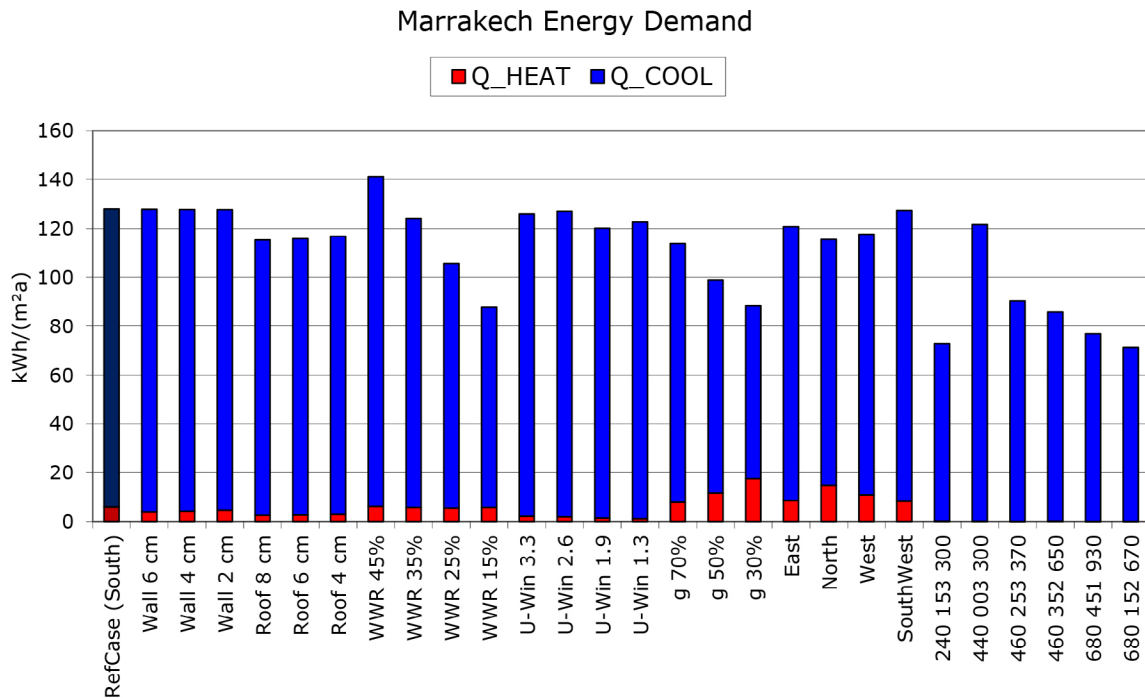
FIGURE 20. Fes parameter variations of the Public Administration Building.**FIGURE 21.** Ifrane parameter variations of the Public Administration Building.

FIGURE 22. Marrakech parameter variations of the Public Administration Building.



- It is interesting to observe that by combining several measures in almost all climate conditions the total energy demands may be lowered to the order of around 60 . . . 80 kWh/(m²a). Only Ifrane with about 40 . . . 60 kWh/(m²a) for cooling stays even lower in its values.
- Even more than in the residential example, a suitable window design is crucial for the success of energy saving measures. In all cases, smaller window-to-wall ratios (WWR) and smaller g-values improve the situation.
- The role of insulation is almost negligible in all climate regions.

5.3 General summary of non-residential buildings

Summarizing the outcomes for all the other building types, it may be concluded that residential buildings could be treated as one group in the future building code. Non-residential buildings should be treated in several classes, dependent on their usage and load profiles.

- Two other residential cases were investigated in the same way. They show similar results. In contrast to a collective residential housing type, single family houses show higher specific energy demands due to increased specific building surface areas and resulting lower WWR values. The above-mentioned order of around 50 kWh/(m²a) is increased to about 75 kWh/(m²a). However, the general behaviour w.r.t. energetic improvements stays the same for all residential cases.
- The school building shows significant heating demand in all investigated climate zones. This is predominantly caused by the high ventilation rates. For this reason, one can observe that even in the Agadir case the combination of measures leads to a significant improvement. Most important is the roof insulation, with increasing dominance of the

heating versus the cooling demand the floor insulation becomes even more important (Fes and especially Ifrane). Low WWR, low window U-values and in tendency high g-values are the best choices for windows. School buildings vary in their total energy demand after optimisation from 50 kWh/(m²a) in Tanger to 130 kWh/(m²a) in Ifrane.

- The hospital results show relatively high energy demands, which are dominated by cooling energy needs. Even for the Ifrane climate, there is a significant cooling load. One reason for this behaviour is the 24 h/day internal load with 10 W/m².

As a typical representative of non-residential buildings with higher ventilation rates and higher internal loads, description and resulting graphics for a public administration building and the complete description of all buildings and simulation results can be found in [11].

6 CONCLUSIONS

A comprehensive study by means of dynamic building simulation of residential and non-residential building types for Moroccan climate conditions leads to the following conclusions:

- At least five different climate zones should be considered separately in a future building code. There are regions with almost no heating but high cooling demand (e.g. Agadir) as well as regions with high heating and no substantial cooling demand (e.g. Ifrane). There exists a range of climatic zones with both heating and cooling demand to be classified by the respective values of these demands.
- Roof insulation is a low-cost measure that improves the energetic behaviour in all locations and both residential and non-residential buildings.
- Also, a low WWR is favourable in all climate zones. Windows should be sized in order to supply sufficient daylight but not larger than that. Otherwise, they increase heating demands in heating periods and cooling demand in cooling periods.
- Large reductions in the heating energy demand are possible where heating is predominant. Wall insulation in addition to roof insulation and double pane glazings are effective measures.
- Reducing cooling loads, especially in non-residential buildings, is harder to achieve and requires a consequent avoidance of unnecessary loads, which in turn again means low glazing areas and low g-values. The reference case energy demand of the public administration building could be reduced by approximately 50% just by introducing a 30% g-value glazing.
- The energetic information gained in this study must now be combined with a cost analysis in order to determine economically feasible marginal conditions for the future Moroccan building code.

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