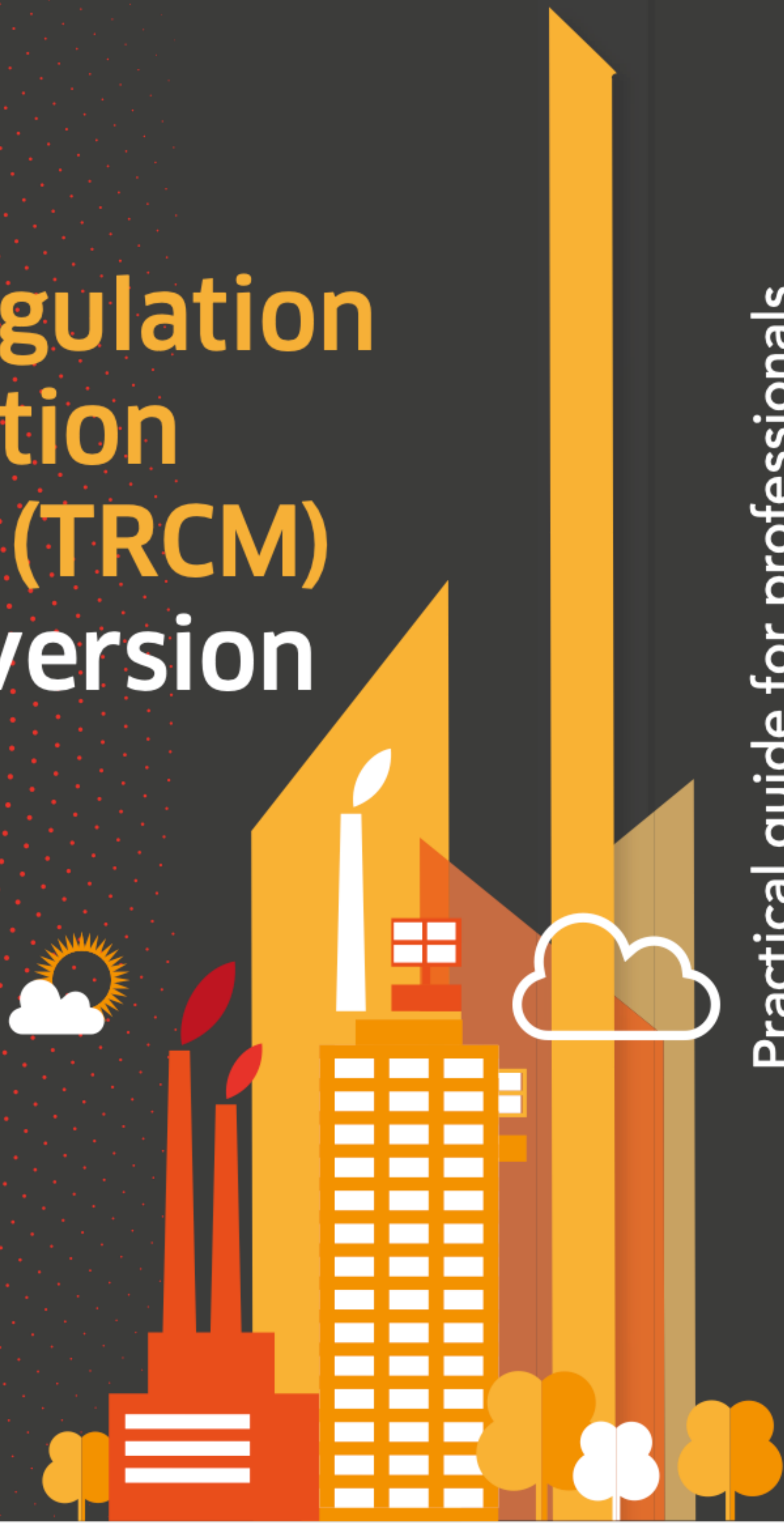
Thermal Regulation of Construction in Morocco (TRCM)

Simplified version

Practical guide for professionals



amee

Moroccan Agency for Energy Efficiency

Thermal Regulation of Construction in Morocco

simplified version

Practical guide for professionals

Executive summary

Developed by ADEREE as a presentation tool of the thermal regulations, this report is especially targeted to building professionals, working on buildings for the residential or service sector (health, tourism, education, administration and commerce).

This guide outlines the technical requirements of the new Thermal Regulation of Construction in Morocco, a part of the project for energy efficiency code in buildings. This code is based on two components, a passive component relating to energy performance requirements of the housing (thermal insulation of walls, orientation, building materials), and an active component (lighting, air conditioning, heating, ventilation and electrical equipment).

For an optimal implementation of the Thermal Regulation of Construction in Morocco, the report also presents the new map of climatic zoning of Morocco, which identifies six climatic areas.

This document defines and describes two approaches. A functional approach, where levels are expressed in terms of annual heating and cooling requirements, in kWh/m²/year, in relation to an internal reference temperature. The second approach is termed prescriptive and complements the first. Levels are expressed, for each building type and climatic zoning, as the maximum heat transfer coefficients (U in W/m2.K) of walls, roof, low floors and as windows solar factor (SF), depending on the ratio of the glazed surface to the outside walls surface.

Social, economic, energetic and environmental impacts expected from the thermal regulation are presented and detailed according to each climatic zoning or building type.

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FOREWORD

The National Agency for the Development of Renewable Energy and Energy Efficiency (ADEREE) has launched an energetic efficiency program in the building sector whose main objective is to reduce energy consumption in this sector. Quantitatively, the program aims at achieving savings of 1.2 Mtoe/year by 2020 and decreasing greenhouse gas emissions by about 4.5 $MteCO_2$.

Thermal Regulation of Construction in Morocco

The implementation of this regulation went through the following steps :

- elaboration of the technical specifications of thermal regulation followed by implementation of the regulatory and normative framework ;
- implementation of a strategic plan and workshops to sensitize stakeholders about energy efficiency measures in building, in particular administration, companies, professionals and the general public ;
- support and technical assistance to professionals and authorities responsible for monitoring compliance with the requirements of thermal performance, to strengthen their proficiency in the analysis of study results in the field of building energy efficiency ;
- creating a favourable investment climate in the field of energy efficiency ;
- development and implementation of a portfolio of demonstration projects incorporating energy efficiency measures ;
- definition of climatic zoning (3 maps, active and passive) ;
- designing control software related to Thermal Regulation of Construction in Morocco.

Energy efficiency of active systems in building

This is mainly to cover the following aspects :

- market analysis and characterization of HVAC equipment, lighting and domestic hot water (DHW) in Morocco ;
- establishment of a regulatory and normative standards framework for the energy performance of HVAC equipment, lighting and DHW;
- implementation of investment promotion measures in the development of the equipment market for HVAC, lighting and energy efficient DHW ;
- i mplementation of a national plan of communication, mobilization and sensitization of the general public ;
- proficiency increase of professionals and authorities responsible for standards enforcing and for the labeling system of energy performance.

This document relates to the first component. It describes the process of developing thermal regulation for residential and commercial buildings as well as the results achieved in terms of :

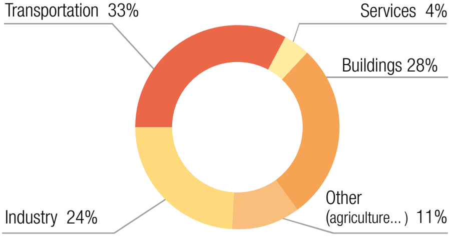
- technical specifications of thermal regulation ;
- socio-economic, energetic and environmental expected impacts from thermal regulation
- projected impacts and their aggregation at the national level.

INTRODUCTION

Construction industry : important worldwide and regional energetic challenges

Worldwide, the building sector alone accounts for around 28 % of the final energy consumption and contribute saboutone - third of CO_2 emissions, as shown in the following graph :

Figure1
Worldwide Final energy consumption in the building sector in 2010

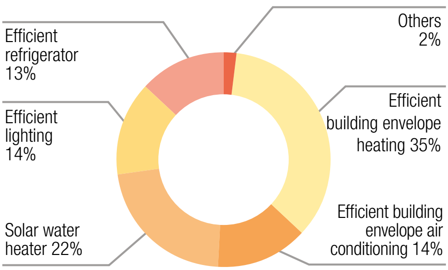


Furthermore, it is estimated that the potential energy savings in this sector is around 40 % worldwide, essentially through cost-effective measures (1). It is also a highly strategic sector due to the long lifetime of buildings : today's buildings will shape in the long term the consumption of tomorrow. A building's well thought design is much more effective and less expensive than a posteriori renovation. If the renovation sector is crucial regarding existing housing stock, new construction must be exemplary.

The southern region of the Mediterranean is no exception to this observation since, on average, the building sector accounts for about 38 % of the energy consumed (this percentage varies between 27 and 65 % depending on the country). It is, moreover, the largest saving opportunity, often around 40 % in most countries in the region (2).

This potential can be achieved through the aggregation of the effect of several individual measures, as the following graph shows (from a study by the Blue Plan in 2009) :

Figure2
Structure of the energy efficiency potential in the region of the southern Mediterranean for the period 2010-2030



Note that improving the thermal performance of the building envelope alone covers 50 % of this potential, through energy savings which it involves in the heating and cooling requirements. This underlines the importance of regulatory measures relating to thermal performance of buildings.

1 According to AIE Scenario 450, 2009.
2 Study on Energy efficiency in building in the Mediterranean, Blue Plan, 2010

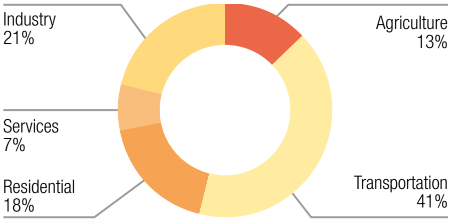
Important energetic and socio-economic challenges in Morocco

Among these sectors, the building sector is the largest energy consumer with a 25 % share of total energy consumption in the country, including 18 % for residential. This energy consumption is expected to increase quickly in the coming years for two reasons :

- significant development of the building stock because of major programs : Plan Azur (hotels), Emergency Education program, 150,000 housing units per year program, hospitals rehabilitation program, etc.
- significant increase in the level of equipment of households in HVAC equipment, lighting and hot water due to the improvement of living standards and lower prices of such equipment (heating, cooling, water heating, refrigeration, etc.).

Figure 3

Structure of consumption by sector



In terms of energy saving, the energetic efficiency program in the construction sector in Morocco aims at a saving of final energy of about 1.22 Mtoe by 2020 (3).

The improvement of thermal performances of the envelope is one of the main structural energetic efficiency measures in this sector, given the duration of its impact over time. This type of measure is all the more important than Morocco today registers unprecedented development of the construction market.

The thermal regulation in new buildings is one of the major instruments for the transformation of the construction market towards a more energy efficient mode.

For these reasons, the regulatory provisions in Morocco focus initially on the performances of the building envelope, but will be expanded in a second time to other important components such as energy equipment, management of services energy, urban planning, etc.

3 « Energetic Efficiency » Action Plan in the construction sector in Morocco, ADEREE.

Regional Benchmarking : quality of the development process, a key factor for the applicability of thermal regulation

Given the energetic stakes that cover the building sector in developing countries and especially in the countries of the southern Mediterranean, most of these have adopted measures of a regulatory or prescriptive for energy efficiency in buildings, as shown in the following table :

However, in reality, the level of implementation of these measures differs significantly from one country to another. The two countries where the thermal regulation is relatively well observed are Turkey and Tunisia. In both countries the regulations were developed through a comprehensive process based on extensive consultation with all stakeholders, with the support of experts, and capacity increasing programs of operators and insulation materials suppliers.

As a general rule the experience of these countries shows that the quality of the regulatory development process is a key factor for its effective applicability.

With the process launched in Morocco, the country is on the way to catch up the gap compared to other countries that have made mandatory the thermal regulation of construction.

Table 1
Thermal regulation in the countries of the southern Mediterranean

Country	Regulatory situation
Jordan	Thermal insulation standard in 1990 EE code mandatory in buildings (in process of validation)
Lebanon	Thermal insulation standard in 2005, reviewed in 2010
Syria	EE code mandatory in buildings (in process of validation)
Turkey	Thermal insulation standard in 2000 Mandatory standard
Algeria	Regulatory Technical Document (RTD) in 1996 Mandatory since 2000
Tunisia	Thermal binding regulations for office in 2008 Thermal binding regulations for residential group in 2009
Egypt	Thermal insulation standard in 1998 EE code in residential constructions, mandatory since 2003 EE code in the service sector, voluntary since 2005

the approach to implementation of thermal regulation in morocco

1

1

THE APPROACH TO IMPLEMENTATION OF THERMAL REGULATION IN MOROCCO

1.1 Objectives

The Thermal Regulation of Construction in Morocco (TRCM) focuses on improving thermal performance :

- reduce the requirement of buildings in heating and air conditioning ;
- improve the comfort of non-air conditioned buildings ;
- reduce the installed power of heating and air conditioning devices ;
- encourage architects, engineers and contractors to use efficient thermal design in the building envelope ;
- make available to the developers, policy makers and donors, a tool to improve the productivity of their investments ;
- help achieving energetic audits of existing buildings.

1.2 Objective and purpose

Besides, the TRCM is a basic document which can be incorporated today in the projects specifications of construction, extension or renovation of buildings. It is a tool for thermal and energy optimization of the building envelope, taking place at the design stage.

It can also be used as a diagnostic tool for existing buildings by providing a framework of acceptable thermal insulation. Then a simulation software could be used to assess the specific annual heating and cooling requirements and compare them with respect to this reference.

Most importantly, all the actors in the field of construction should then be trained in the application of TRCM. Demonstration and information on the ease and flexibility of the application of its provisions are indispensable to convince of its interest. A smart action in this direction will quickly reach the expected energy savings in the building sector.

1.3 Target of Thermal Regulation in Morocco

1 .3.1. Cover most types of buildings…

Thermal regulation, the subject of this report, concerns only the building envelope and covers both the housing and service sector buildings.

In housing, the settlement will cover a priori all socio-economic categories of buildings, including :

- economic ;
- high-end.

In the service sector, four segments are particularly covered, namely :

- hotels ;
- administrative buildings (offices) ;
- education and higher education buildings ;
- hospitals.

1 .3.2. Focus on new constructions…

Although the issue of energetic efficiency in existing buildings is very important given the magnitude of the stock in Morocco, the proposed thermal regulation covers, at first, only new buildings.

The segment of existing buildings can be treated through energy audits and implementation of energetic efficiency measures deriving from it.

1.4 Development process

The methodology used to conduct the development of the Thermal Regulation of Construction in Morocco (TRCM) is an iterative process based on extensive consultation with all stakeholders of the construction industry, as evidenced by a series of exchange and validation meetings.

The logical sequence of this process was carried out via six major phases :

- preparing data and assumptions ;
- climatic zoning ;
- thermal simulations and parametric analysis ;
- assesment of socio-economic impacts of thermal regulation ;
- political dialogue with the institutions in charge of target sectors ;
- implementation of the thermal regulation.

1 .4.1. Preparation of data and assumptions

During this phase, data and assumptions required for different phases of the study were prepared on the basis of documents and sources of information available in Morocco, such as :

- data on building materials and glazing used in Morocco (nature, characteristics thermo physical, price, etc.) ;
- energy equipment for heating and air conditioning (characteristics, equipment rates, prices, etc.) ;
- building concepts of construction ;
- existing building stock and its characteristics ;
- demographic current data and projections ;
- energy consumption by sector ;
- heating mode and energy used ;
- occupancy profile of buildings ;
- climatic files, etc.

1 .4.2. Climatic zoning

The work on climatic zoning was made in close coordination between the Direction de la Météorologie Nationale (DMN) and ADEREE, with the support of international expertise.

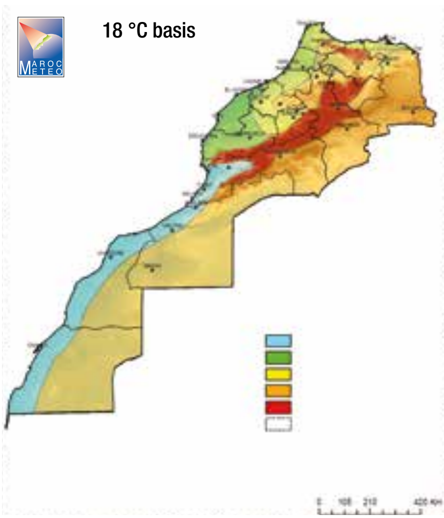
The Moroccan territory was divided into homogeneous climatic zones based on the analysis of climate data recorded by 37 meteorological stations over a 10 year period (1999-2008). The zoning was performed according to the criterion of the number of degree days of winter and the number of degree days of summer.

Two types of zoning have been established by DMN :

- zoning based on heating degree days at 18 °C basis ;
- zoning based on cooling degree days cooling at 21 °C basis.

Heating Degree Days : measurement of the difference between the average temperature of a given day and a reference temperature, which translates to the requirement in heating. The reference temperature used was 18 °C because, on average, when the outdoor temperature falls below this level, one must heat the interior to maintain a comfortable temperature.

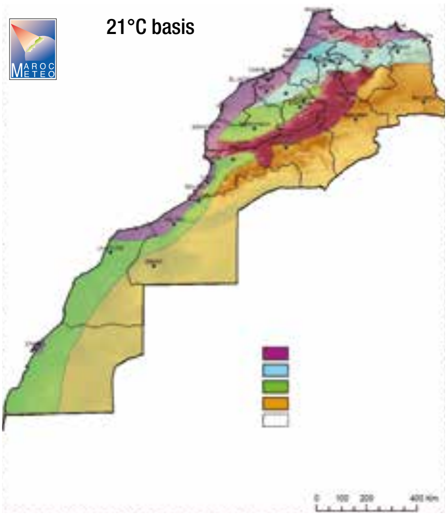
Figure4
Climatic zones in Morocco in heating degree days



Cooling degree days : measurement of the difference between the average temperature of a given day and a reference temperature, which translates to the requirement in air conditioning during the hot summer months. The reference temperature used is 21 °C. When the outside temperature is 21 °C internal gains can increase the indoor temperature to more than 24 °C - 26 °C which requires cooling.

Figure 5

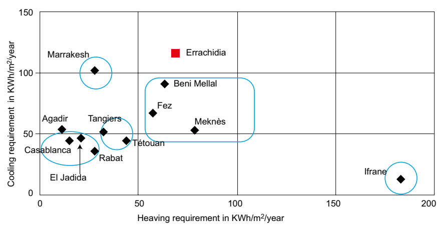
Climatic zones in Morocco in cooling degree days



However, for practical reasons it is not possible to adopt two different seasonal zonings. For the purpose of thermal regulation, a unique climatic zoning was carried out by international experts with annual weather hourly files, based on simulation results of the annual heating and cooling requirements for the buildings in eleven Moroccan representative cities.

Figure 6

Specific energetic requirements for the heating and cooling : 12 locations in Morocco



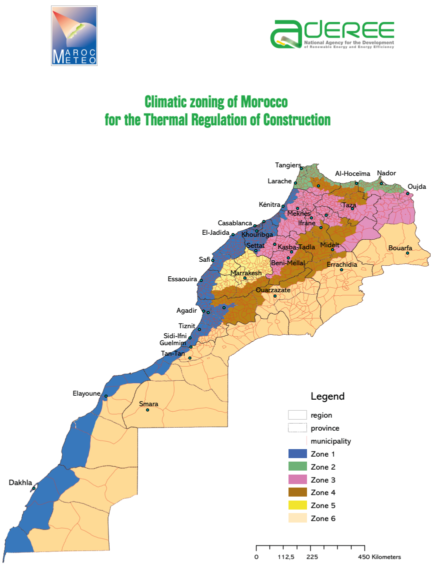
Thus, ultimately, the final zoning map includes six climatic zones, aligned to administrative limits for easy and efficient implementation of the new regulation. These areas are climatically represented by the following cities :

Table 2 Climatic zones	
Zone 1	Agadir
Zone 2	Tangiers
Zone 3	Fez
Zone 4	Ifrane
Zone 5	Marrakesh
Zone 6	Errachidia

The following map shows the climatic zones adopted for thermal regulation.

Figure 7

ic zones in Morocco



1.4.3. Thermal model and parametric analysis

The purpose of these simulations is to establish the optimal technical options to significantly improve the thermal performance of targeted buildings compared to the current situation, and make it a reference. For this, a series of thermal simulations were performed on the reference buildings using TRNSYS software.

1.4.3.1. Selection of reference buildings

In coordination with the government departments in charge of the sectors, seven reference buildings were chosen for thermal simulations :

- residential buildings :

- an economic apartment building ;
- a semi-standing apartment building ;
- an economic detached type house

- commercial buildings :

- a hotel ;
- a hospital ;
- a school ;
- an administrative building.

These reference buildings, selected for parametric analysis, represent common cases of construction and equipment in Morocco.

Figure 8
Typical Plan

1 .4.3.2. Parametric energetic analysis

The parametric energetic analysis consists in varying the parameters of the reference building envelope, one by one, to simulate the impact of each change on the annual requirement of heating and cooling under standard conditions and in different climatic zones. The simulated parameters are :

- walls insulation (3 or 4 variants of insulation thickness) ;
- roof insulation (3 or 4 variants of insulation thickness) ;
- low floors insulation (3 or 4 variants of insulation thickness) ;
- windows insulation (3 and 4 variants of windows) ;
- solar protection of glazings (3 or 4 variants of glazing Solar Factor "SF") ;
- sunscreen windows (3 or 4 variants of canopies and 3 or 4 variants of side overhangs) ;
- building orientation (two different orientations) ;
- 5-10 combinations of the most characteristic previous settings.

The simulated insulation has a thermal conductivity of $\lambda = 0.04$ W/m2.K for walls, low floor and roof.

The total number of simulations is greater than 400. Simulations were performed with indoor conditions of 24 °C and 26 °C for cooling and 20 °C for heating.

The following figures show some simulation results.

Figure 9
Agadir : annual energy requirement

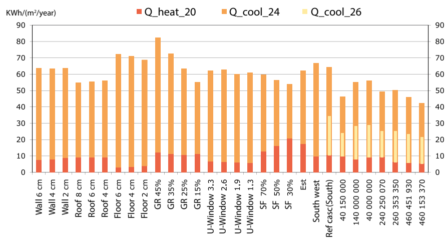
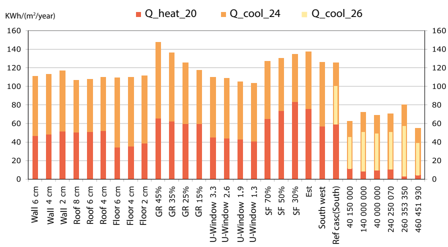


Figure 10
Fez : annual energy requirement



Thus, for each simulated parameter, new thermal requirements are assessed and compared to the requirements of the reference case.

For combinations, the code example (462,451,930) is interpreted as follows :

Table 3 Example of energy code					
Wall	**Roof**	**Floor**	**GR**	**U Window**	**SF**
4	6	2	45	1.9	30
4 cm insulation	6 cm insulation	4 cm insulation	%	W/m2.K	%

λ= *0.04 W/m2.k*

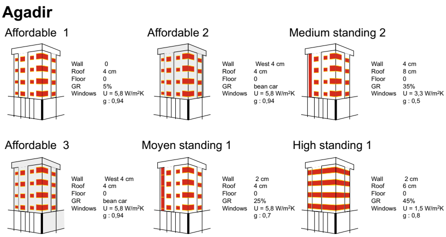
1.4.4. Parametric analysis of extra costs

The purpose of this analysis is to define, for each simulated parameter, the extra investment costs related to the implementation of each option. It also computes the investment cost reduction (or increase) for heating and cooling (due to the change in installed power) taking into account the varying costs of maintenance.

The extra investment costs were determined by the architect on the basis of insulation materials prices currently available in Morocco (wall insulation, double glazing window, etc.).

The additional costs were estimated for different levels of glazing (15 %, 25 %, 35 % and 45 %) to give more flexibility to designers, as shown in the following examples :

Figure 11
Parametric analysis in Agadir



1.4.5. Definition of minimum technical specifications for buildings' thermal performance

Taking into account the additional costs of investment on the one hand and thermal simulations on the other hand, an iterative process allowed setting reasonable levels of requirements to be considered as regulatory levels, in terms of performance of the envelope. These levels were defined from the energy saving options that show a good technical and economic compromise.

The TRCM defines performance criteria for the components of the building envelope whose levels will lead to reduce (i) the requirement for heating and cooling, (ii) energy consumption related to these entries and (iii) the electrical power required to operate the building. For buildings without air conditioning they will reduce the periods of thermal discomfort.

The minimum technical specifications for thermal performance can be expressed, for each climatic zone and each building type, in two ways. Both approaches provide professionals involved in the design of the components of the building envelope a great flexibility in the application of TRCM.

1.4.5.1. Comprehensive approach called functional

Specifications are expressed in terms of minimum annual requirements of heating and cooling, on the basis of internal reference temperatures (20 °C for heating and 26 °C for air conditioning). However, verification of these specifications requires the use of a simulation tool. Simplified simulation software will be developed and made freely available to users. Nevertheless, the use of heavy software like TRNSYS or VisualDO3 or simpler software like HAP and CODYBA remain valid for large projects that justify the use of this kind of software (especially when sizing HVAC systems).

1.4.5.2. Simplified approach called prescriptive

The thermal properties of the walls of a building envelope correspond to the heat transfer coefficients (U) of roofs, exterior walls, floors on piles and glazing windows, as well as the solar factor (SF *) of windows and the thermal resistance (R) of slab-on-grade floors.

- Calculation of the overall glazing ratio GR : The GR of the heated and/or cooled spaces of a building is defined by the ratio of the total area of glazed windows on the total area of all exterior walls :

$$TGBV = \frac{\sum \text{area of glazing of outside walls, heated and/or cooled}}{\sum \text{area of outside walls, heated and/or cooled}}$$

- Calculation of thermal transmission coefficient U : The thermal transfer coefficient U is the heat flow ratio in continuous operation for one square meter divided by the temperature difference between the environments of each side of the wall. This coefficient is measured in W/(m².K). It is defined as follows :

$$U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_e} + \sum \frac{e_i}{\lambda_i} + \sum R_j}$$

λi : thermal conductivity of material « i » of the wall (W/m2.K)

ei : thick ness of the wall material (m)

Rj : thermal résistance (m2.K/W)

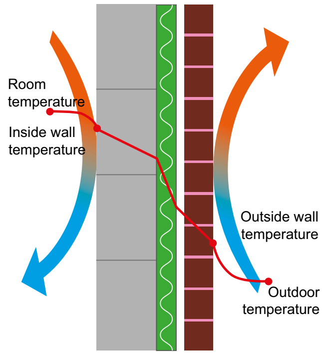
superficial thermal resistance of a wall on the inner and outer surfaces by radiation and convection (m2.K/W).

$\frac{1}{h_i} + \frac{1}{h_e}$: Conventional values of superficial thermal resistances :

Vertical wall : $\frac{1}{h_i} + \frac{1}{h_e} = 0.17$ m2.K/W

Horizontal wall : $\frac{1}{h_i} + \frac{1}{h_e} = 0.22$ m2.K/W

Figure 12.
Thermal transfer coefficient "U"



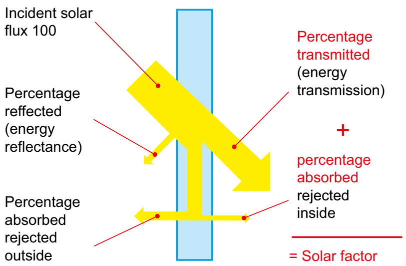
The heat exchanges through the envelope are proportional to coefficient "U". The thermal regulation imposes a maximum value of « U » for each item in the envelope.

- Calculation of Solar Factor SF :

The solar factor SF (called Solar Heat Gain Coefficient, SHGC) is the amount of solar energy expressed as a percentage (%) which is measured behind windows exposed to sun radiations (without external shadings and internal sunscreens).

The heat percentage that is measured behind the glass is the result of very complex phenomena of transmission, absorption and reflection taking place in the window system. The SF coefficient is given by the manufacturer of the windows.

Figure 13
Solar factor SF



SF* : the equivalent solar factor of windows is the amount of solar energy as a percentage (%), which is measured behind windows associated with their architectural outdoor shading.

1.4.6. Analysis of socio-economic impacts

The objective of this analysis is to check the economic feasibility for the various actors by assessing the positive and negative impacts that each of them may incur through the application of thermal regulation. Moreover the results of this analysis are the basic data for discussions with the various stakeholders in the sector.

The analysis then focuses on different indicators :

1.4.6.1. For the final consumer

- incremental investment costs related to the implementation of technical specifications ;
- gains in final energy (fuel and electricity) ;
- gains on energy bills ;
- gains on investments related to the sizing of air conditioning and heating ;
- payback compared to additional investments costs.

1.4.6.2. At the State and community level

- gains in primary energy ;
- subsidies avoided by the State on conventional energy ;
- impacts on the electric load curve at the national level ;
- avoided electricity capacity and significant investments deferred ;
- gas emissions avoided ;
- cost of primary toe saved compared to the cost of supply on the international market, etc.

The analysis is first done from a microeconomic point of view, i.e. at the building level, comparing the impacts with that of constructions complying with the thermal regulation.

Then, a prospective impact analysis is conducted by aggregating the effects on the entire projected stock, based on assumptions about the level of equipment in heating and cooling devices of the target.

1.4.7. The technical and political dialogue

To ensure the future applicability of the projected thermal regulation, it is important that the development of this regulation is based on a consensual and participatory approach at both technical and political levels.

For this purpose, the proposed technical specifications are first discussed and validated through expert workshops involving specialized engineers, architects, researchers, academics, real estate operators, technical staff from relevant government departments, etc.

Next, in order to ensure political support of sectorial partners with the future regulation, consultation workshops are organized with the different government departments, namely : Housing, Tourism, Health, National Education, Energy and Mines, and Finance. This discission is centered around the evaluation of socio-economic impacts of the regulation on the different actors.

At the same time, consultations in regional meetings were held with local stakeholders in different regions of the country.

In the end, the consultations process ended with a national conference which prepared the final draft of the legislative framework on the basis of a national consensus.

Thermal regulation in the housing sector

2

2

THERMAL REGULATION IN THE HOUSING SECTOR

2.1 Technical Specifications of thermal regulation in residential buildings

2.1.1. Functional approach

Les spécifications techniques minimales des performances thermiques des bâtiments sont fixées par le RTCM conformément à l'approche performancielle suivante:

Table 4 Thermal performance of residential buildings by area in kWh/m²/year		
Agadir	Z1	40
Tangiers	Z2	46
Fez	Z3	48
Ifrane	Z4	64
Marrakesh	Z5	61
Errachidia	Z6	65

To facilitate its application, requirements are the same for different socio-economic categories of buildings. They differ from one climatic zone to another due to the difference of the respective climatic conditions.

2.1.2. Prescriptive approach

These specifications can be expressed in a prescriptive approach, depending on the area, as shown in the table below.

Thermal resistances listed here are solely those of the insulation material, excluding any interior air films, as well as of the thermal resistance of the soil and of other components of the concrete slab floor.

For the minimum thermal resistance for low floors, the obligation is limited only to the slab-on-grade floors of air-conditioned or heated spaces.

Floor tiles should be insulated with thick insulation providing a thermal resistance as shown in the table.

The low floors on piles exposed to the outside air will be treated as roofs.

	T able 5 Heat transfer coefficient U and thermal resistance R in residential buildings					
	Glazing rotio GR	U of exposed roofs (W/m2.K)	U of outdoor walls (W/m2.k)	U of glazing (W/m2.k)	R minimum of floor on slab (m2.k/W)	Glazing solar factor SF*
Climatic zone Z1 (Ref. Agadir)	≤ 15 %	≤ 0,75	≤ 1,20	≤ 5,80	NR	NR
	16-25 %	≤ 0,75	≤ 1,20	≤ 5,80	NR	North : NR Others : ≤ 0.7
	26-35 %	≤ 0,75	≤ 1,20	≤ 3,30	NR	North : NR Others : ≤ 0.5
	36-45 %	≤ 0,65	≤ 1,20	≤ 3,30	NR	North : ≤ 0.7 Others : ≤ 0.3
Climatic zone Z2 (Ref. Tangiers)	≤ 15 %	≤ 0,75	≤ 0,80	≤ 5,80	NR	NR
	16-25 %	≤ 0,65	≤ 0,80	≤ 3,30	NR	North : NR Others : ≤ 0.7
	26-35 %	≤ 0,65	≤ 0,70	≤ 3,30	NR	North : NR Others : ≤ 0.5
	36-45 %	≤ 0,55	≤ 0,60	≤ 2,60	NR	North : ≤ 0.7 Others : ≤ 0.3
Climatic zone Z3 (Ref. Fez)	≤ 15 %	≤ 0,65	≤ 0,80	≤ 3,30	≥ 0,75	NR
	16-25 %	≤ 0,65	≤ 0,80	≤ 3,30	≥ 0,75	North : NR Others : ≤ 0.7
	26-35 %	≤ 0,65	≤ 0,70	≤ 2,60	≥ 0,75	North : NR Others : ≤ 0.5
	36-45 %	≤ 0,55	≤ 0,60	≤ 1,90	≥ 0,75	North : ≤ 0.7 Others : ≤ 0.5
Climatic zone Z4 (Ref. Ifrane)	≤ 15 %	≤ 0,55	≤ 0,60	≤ 3,30	≥ 1,25	NR
	16-25 %	≤ 0,55	≤ 0,60	≤ 3,30	≥ 1,25	North : NR Others : ≤ 0.7
	26-35 %	≤ 0,55	≤ 0,60	≤ 2,60	≥ 1,25	North : ≤ 0.7 Others : ≤ 0.6
	36-45 %	≤ 0,49	≤ 0,55	≤ 1,90	≥ 1,25	North : ≤ 0.6 Others : ≤ 0.5
Climatic zone Z5 (Ref. Marrakesh)	≤ 15 %	≤ 0,65	≤ 0,80	≤ 3,30	≥ 1,00	NR
	16-25 %	≤ 0,65	≤ 0,70	≤ 3,30	≥ 1,00	North : NR Others : ≤ 0.7
	26-35 %	≤ 0,55	≤ 0,60	≤ 2,60	≥ 1,00	North : ≤ 0.6 Others : ≤ 0.4
	36-45 %	≤ 0,49	≤ 0,55	≤ 1,90	≥ 1,00	North : ≤ 0.5 Others : ≤ 0,3
Climatic zone Z6 (Ref. Errachidia)	≤ 15 %	≤ 0,65	≤ 0,80	≤ 3,30	≥ 1,00	NR
	16-25 %	≤ 0,65	≤ 0,70	≤ 3,30	≥ 1,00	North : NR Others : ≤ 0.7
	26-35 %	≤ 0,55	≤ 0,60	≤ 2,60	≥ 1,00	North : ≤ 0.6 Others : ≤ 0.4
	36-45 %	≤ 0,49	≤ 0,55	≤ 1,90	≥ 1,00	North : ≤ 0.5 Others : ≤ 0.3

NR : no requirement.

2.2 socio-economic, energy and environmental impacts expected from thermal regulation

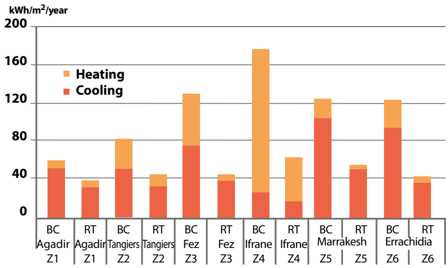
2.2.1. Impacts to the final consumer

The feasibility and effectiveness of the implementation of the proposed regulation are largely dependent on the economic stakes, for the final consumer, of the recommended measures on the envelope. It is therefore necessary to analyze the advantages and disadvantages of these provisions for the end user.

2.2.1.1. Impact on thermal heating and cooling requirements

Compliance with the requirements of the thermal regulation proposed for residential buildings should lead to significantly reduced requirements in heating and cooling, compared with the reference base, as shown in the chart below.

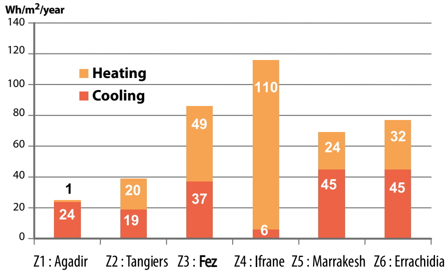
Figure 14
Comparison between Basic case (BC) and thermal regulation (RT) residential building (T = 26 °C in summer)



depending on climatic zone

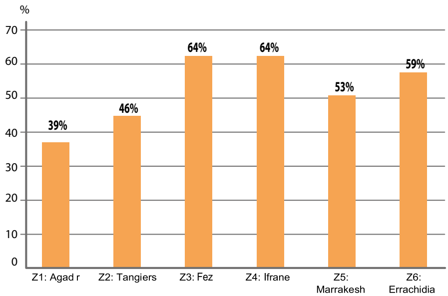
Annual savings in heating and cooling rang e from 25 kWh/m²/year in the area represented by Agadir climate to 116 kWh/m²/year in the cold zone represented by Ifrane. It should be noted that, given the general nature of climate in Morocco, heating gains are generally larger than those for air conditioning, except for zones with warm climates, such as Marrakesh and Errachidia.

Figure 15
Gains in heating and cooling requirement depending on climatic zone



In relative terms, the application of thermal regulation should allow for gains from 40 % to 65 % depending on the climatic zone compared with the reference base, as shown in the chart below.

Figure 16
Impacts of thermal regulation on reducing heating and cooling requirements of residential buildings (T = 26 °C in summer) to Morocco (% reduction)



If the house is heated and/or air-conditioned, these gains will be translated by an economy on the final energy consumption. If the household does not heat or cool, the application of the thermal regulation will be translated into an improvement of the thermal comfort.

2.2.1.2. Impact on final energy consumption

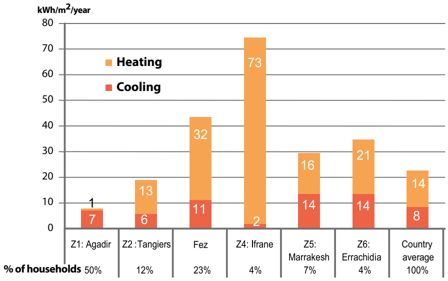
The requirements of thermal regulation allow final energy savings to consumers of about 22 kWh per year per m² of covered building (4). These savings range from 8 kWh/m²/year (zone Z1) to 75 kWh/m²/

year (zone Z4) according to climatic zone.

These savings were evaluated taking into account the predominant modes of heating and cooling in different parts of Morocco and the average yield of the equipment used.

Figure 17

Saving in final energy for heating and cooling depending on climatic zone



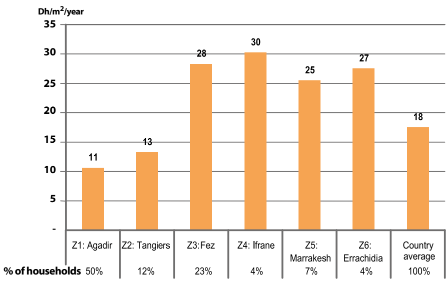
2.2.1.3. Impact on the energy bill of end user

With current energy prices, these savings mean saving on the energy bill of heating and air conditioning for the end consumer.

This gain is estimated to average 18 Dh/m²/year and ranges from 11 Dh/m²/year in the zone Z1 representing over 50 % of homes and 30 Dh/m²/year in the Z4 area which represent only 4 %.

Figure 18

Gains on energy bills for consumers depending on climatic zone



2.2.1.4. Additional costs implied by compliance with the regulation

Compliance with technical specifications of the regulation implies an average additional investment of about 112 Dh/m², averaging 3.2 % of average construction cost (5).

This additional cost is higher or lower depending on the area and by type of habitats, given the difference of the measures to be implemented. And it ranges from 43 Dh/m² in the Agadir area for deluxe apartments to 315 Dh/m² for economic villas in areas of Ifrane and Fez.

In relative terms, this extra cost is a particularly high percentage of construction costs for the category of affordable housing, especially along the seaside (Z1 and Z2).

Figure 19

Additional cost of investment generated by the thermal regulation depending on climatic zone

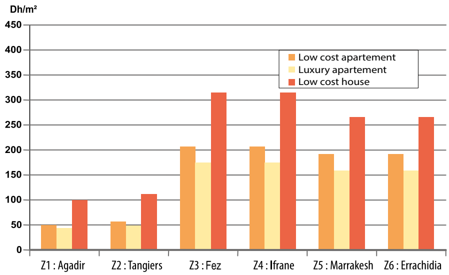
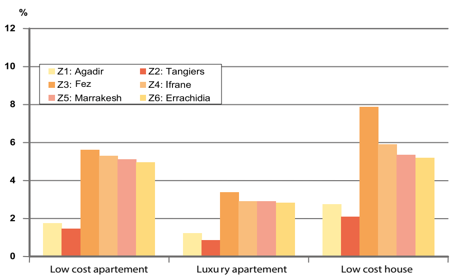


Figure 20

Percentage of extra investment due to RTCM by type of housing and zone



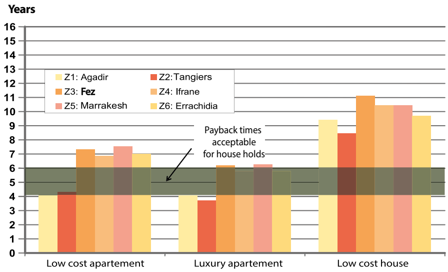
1 Average weighted of current habitat distribution according to climatic zones

2.2.1.5. Profitability of thermal regulation for consumers

5 Average weighted of current habitat distribution according to climatic zoning For the final consumer, economic efficiency measures implied by the regulation substantially determine the degree of its applicability.

This profitability can be assessed through the indicator of payback return, the number of years required to cover the additional investment by the annual saving on energy bills.

Figure 21
Investment payback the end user depending on the area and type of habitat



On average, across the country, the investment payback weighted by zones and habitat types is about 6.5 years. It falls within the limit of a favourable investment decision for most households.

Payback for the end user varies as a function of climatic zone and housing type. As shown in the chart above, the lowest returns are essentially found in inland areas (outside the coasts). For housing categories, the affordable collective residential has the lowest profitability.

In conclusion, the economic attractiveness of thermal regulation is limited for certain segments of the housing market, particularly in inland areas of the country (Z3, Z4, Z5 and Z6). In these zones the return on investment for the final consumer exceeds the range of minimum profitability usually acceptable by households.

2.2.2. Impacts for the State and community

Impact of the implementation of the thermal regulation for the community and the State can be measured in several ways :

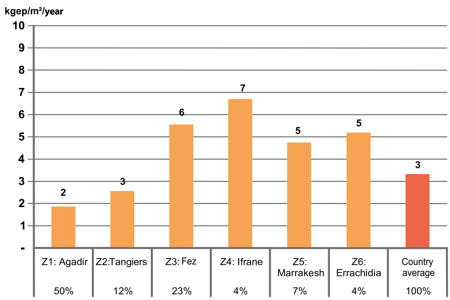
- reduction in the energy supply bill for the country due to primary energy savings ;
- gains in public investment through electricity production capacity avoided due to the reduction in demand for air conditioning load ;
- gains in subsidies to the substituted conventional energy (including LPG) ;
- greenhouse gas emissions reduction, which reinforces Morocco's contribution to the fight against climate change.

2.2.2.1. Gain in primary energy

The gain in primary energy for the country would average 3 Kgoe/m²/year.

It varies depending on the climatic characteristics of areas : from 2 Kgoe/m²/year in zones Z1 and Z2 up to 7 Kgoe/m²/year in Ifrane area.

Figure 22
Gain in primary energy according to climatic zone



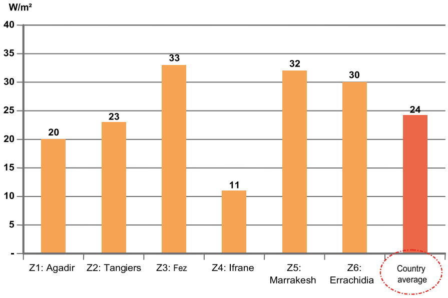
2.2.2.2. Gain in installed capacity

In terms of power consumption, the implementation of the thermal tegulation will prevent an average consumption of 24 W/m². This translates into an approximate investment avoided of 200-240 Dh/m² for the construction of additional power generation capacity.

1 Moyenne pondérée selon la répartition actuelle de l'habitat selon les zones climatiques.

Figure 23

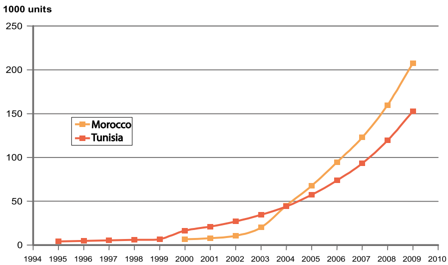
Country average Fez Electrical power avoided by climatic zone



The development of air conditioning in Morocco will be an important future challenge in light of the market development for air conditioners in recent years. This is the result from the improvement of household's living standards and their yearning for better living standards. The following chart, computed from data collected from various sources, including from the largest distributors of electrical equipment, illustrates this strong evolution. In 2009, there were approximately 200,000 air conditioners sold on the Moroccan market.

Figure 24

Estimate of the evolution of the annual air conditioning market in Morocco and Tunisia



This development induces a gradual and structural transformation of the national electrical load curve with the rapid increase of the peak dayload in summer due to air conditioning, as observed in Tunisia over the past ten years.

Observation of the evolution of the Moroccan load curve shows the beginnings of such a phenomenon, with a small peak which begins to appear during a typical summer day.

Figure 25

Annual peak of July 1, 2008

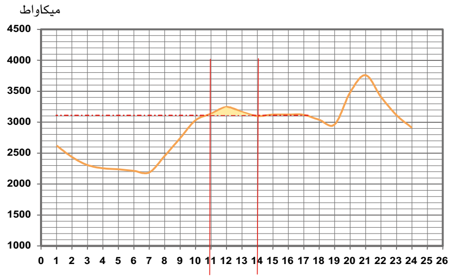
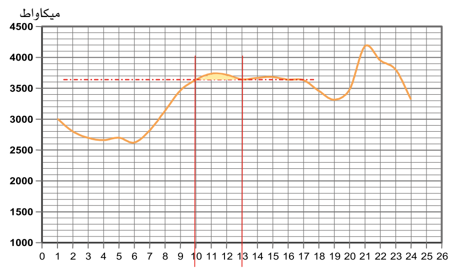


Figure 26

Annual peak of July 1, 2008



2.2.2.3. Gain of public subsidies on conventional energy

Consumer prices of some energy products are subsidized by the government for social or economic reasons.

Economies in the consumption of these products can reduce public subsidies.

The amount of public subsidy for a given product can be estimated by the difference between the cost of supply of the product in the international market and the price to the final consumer.

Main energy products whose consumption is avoided by insulation measures induced by heat regulation in residential buildings are the LPG (butane bottle) used for heating and electricity used for air conditioning.

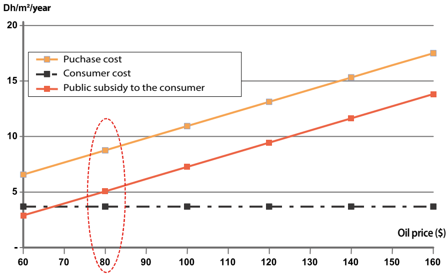
To compute gains in government subsidies to conventional energy, only LPG subsidies were considered, assuming that electricity cost reflects prices truth.

Accordingly subsidies avoided depend on the level of international oil prices, considering that the domestic price of LPG remains regulated.

The chart below shows the level of subsidies avoided by the State based on the oil price for one m² heated under thermal regulation.

For instance, with an oil price of $ 80/barrel, the current State subsidy for LPG heating of one m² of housing is estimated at about 5 Dh/m²/year. Such subsidy would double if oil price reach $ 120/barrel.

Figure 27
Public subsidy for LPG heating of 1 m² of housing with reference to the international oil price



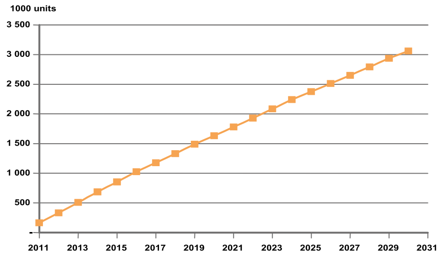
2.3 Prospective impacts

2.3.1. Anticipation of the new urban housing

The forecast of the new housing urban stock was based on state projects in construction programs in the short and medium term as well as the outlook of the National Department of Statistics of the High Commission for Planning.

The stock which will be built over the next 20 years is estimated at about 3 million units, as shown in the chart below.

Figure 28
New building stock accumulated from 2011

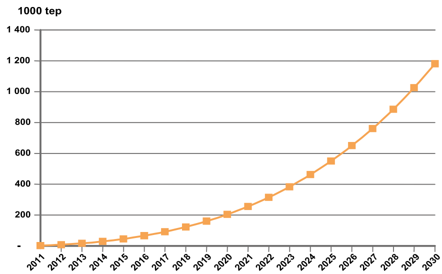


2.3.2. Aggregation of primary energy savings

The primary energy savings made by each dwelling under thermal regulation are aggregated on the entire new housing stock. This aggregation takes into account the assumed trend of heating and air conditioning increase in Morocco, which result from retrospective analysis and benchmarking with other similar countries.

The analysis shows that the annual energy savings will reach 1.2 Mtoe of primary energy in the next 20 years (2030), as the graph below shows:

Figure 29
Annual savings in primary energy



Accumulated over the lifetime of the energy efficiency measures (30 years minimum), energy savings are estimated at around 20 Mtoe, or about 5 times the current annual consumption of the entire construction industry.

The cost of primary energy saved would be in this case about 1,100 Dh/toe compared to the cost of purchasing LPG toe in the international market which is in the order of Dh 5,600 for a crude oil price of $ 80.

2.3.3. Avoided electricity capacity

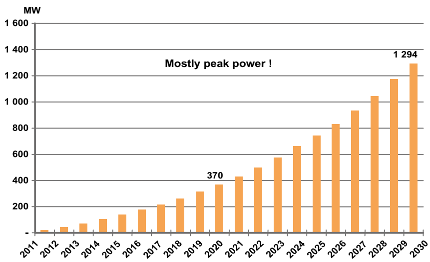
The aggregation of the reduction of power demand of air conditioners in residential buildings will alleviate in the long term the build up of additional capacity.

This avoided total capacity would be 370 MW by the next 10 years and 1,300 MW for the next 20 years.

The economic value of this avoided capacity is mostly significant in that it will certainly occur during the peak summer load due to air conditioning, as already observed in Tunisia over the past ten years.

In financial terms, investment gains deferred due to capacity gains can be estimated at about 4,150 MDh in 10 years and 14,600 MDh by 2030.

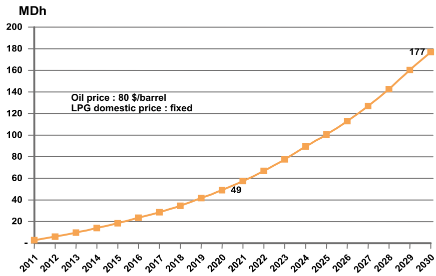
Figure 30
Electrical power avoided by the implementation of thermal regulation



2.3.4. Avoided subsidies

Assuming an average oil price of $ 80/barrel and an unchanged butane bottle price, subsidies avoided by the State on energy product would be about 177 MDh at the 2030 horizon. Cumulative 20-year gains are estimated at nearly 1,340 MDh.

Figure 31.
Annual publer subsidies avoided



2.3.5. Positive by-products

▸ Avoided CO_2 emissions :

Considering emissions in Morocco from fuels and electricity generation, the cumulative avoided emissions over the next 20 years period would amount to about 20 MteCO_2.

▸ Creation of jobs and opportunities :

Implementation of the regulation will create about 18,000 permanent jobs by 2030 and will generate additional business volume of more than 20 billion Dh for Moroccan companies.

Table 6
Job creation and business volumes

	2011	2015	2020	2025	2030
Permanent jobs created	906	4,926	9,470	13,801	17,801
Cumulative volume of investments (MDh)	1,047	5,694	10,948	15,954	20,579

3

THERMAL REGULATION IN THE SERVICE SECTOR

3

THERMAL REGULATION IN THE SERVICE SECTOR

The proposed thermal regulation targets the four major branches of the service sector, namely :

- administrative buildings ;
- schools ;
- hospitals;
- hotels.

The technical specifications of the regulation and its impacts are presented for each branch.

3.1 Technical Specifications

3.1.1. Functional approach

According to the functional approach, the minimum technical specifications of thermal performance of buildings are set by the RTCM as follows :

Table 7.
Specific thermal annual maximum requirements for heating and cooling in the service sector in kWh/m^2/an/year

	Schools	Administrations	Hospitals	Hotels
Agadir Z1	44	45	72	48
Tanger Z2	50	49	73	52
Fès Z3	61	49	68	66
Ifrane Z4	80	35	47	34
Marrakech Z5	65	56	92	88
Errachidia Z6	67	58	93	88

3.1.2. Prescriptive approach

Prescriptive specifications are expressed in the same way for the entire service sector with the aim of simplifying the implementation of thermal regulation. These prescriptive specifications are presented by climatic zone in the table below.

Thermal resistances listed here are solely those of the insulation material, excluding any interior air films, as well as of the thermal resistance of the soil and of other components of the concrete slab floor.

Table 8.
The regulatory limits on thermal characteristics of the envelope in the service sector

	Glazing ratio GR	U of exposed roofs (W/m².K)	U of outdoor walls (W/m².k)	U of glazing (W/m².k)	R minimum of floor on slab (m².k/W)	Glazing solar factor SF*
Climatic zone Z1 (Ref. Agadir)	≤ 15 %	≤ 0.75	≤ 1.20	≤ 5.80	NR	NR
	16-25 %	≤ 0.65	≤ 1.20	≤ 5.80	NR	North : NR Others : ≤ 0.7
	26-35 %	≤ 0.65	≤ 1.20	≤ 3.30	NR	North : NR Others : ≤ 0.5
	36-45 %	≤ 0.55	≤ 1.20	≤ 3.30	NR	North : ≤ 0.7 Others : ≤ 0.3
Climatic zone Z2 (Ref. Tangiers)	≤ 15 %	≤ 0.65	≤ 0.80	≤ 5.80	NR	NR
	16-25 %	≤ 0.65	≤ 0.80	≤ 3.30	NR	North : NR Others : ≤ 0.7
	26-35 %	≤ 0.65	≤ 0.60	≤ 3.30	NR	North : NR Autres : ≤ 0.5
	36-45 %	≤ 0.55	≤ 0.60	≤ 2.60	NR	North : ≤ 0.7 Others : ≤ 0.3
Climatic zone Z3 (Ref. Fez)	≤ 15 %	≤ 0.65	≤ 0.80	≤ 3.30	≥ 0.75	NR
	16-25 %	≤ 0.65	≤ 0.80	≤ 3.30	≥ 0.75	North : NR Others : ≤ 0.7
	26-35 %	≤ 0.55	≤ 0.70	≤ 2.60	≥ 0.75	North : NR Others : ≤ 0.5
	36-45 %	≤ 0.49	≤ 0.60	≤ 1.90	≥ 0.75	North : ≤ 0.7 Others : ≤ 0.5
Climatic zone Z4 (Ref. Ifrane)	≤ 15 %	≤ 0.55	≤ 0.60	≤ 3.30	≥ 1.25	NR
	16-25 %	≤ 0.55	≤ 0.60	≤ 3.30	≥ 1.25	North : NR Others : ≤ 0.7
	26-35 %	≤ 0.49	≤ 0.60	≤ 2.60	≥ 1.25	North : ≤ 0.7 Others : ≤ 0.6
	36-45 %	≤ 0.49	≤ 0.55	≤ 1.90	≥ 1.25	North : ≤ 0.6 Others : ≤ 0.5
Climatic zone Z5 (Réf. Marrakesh)	≤ 15 %	≤ 0.65	≤ 0.80	≤ 3.30	≥ 1.00	NR
	16-25 %	≤ 0.65	≤ 0.70	≤ 3.30	≥ 1.00	North : NR Others : ≤ 0.7
	26-35 %	≤ 0.55	≤ 0.60	≤ 2.60	≥ 1.00	North : ≤ 0.6 Others : ≤ 0.4
	36-45 %	≤ 0.49	≤ 0.55	≤ 1.90	≥ 1.00	North : ≤ 0.5 Others : ≤ 0.3
Climatic zone Z6 (Réf. Errachidia)	≤ 15 %	≤ 0.65	≤ 0.80	≤ 3.30	≥ 1.00	NR
	16-25 %	≤ 0.65	≤ 0.70	≤ 3.30	≥ 1.00	North : NR Others : ≤ 0.7
	26-35 %	≤ 0.55	≤ 0.60	≤ 2.60	≥ 1.00	North : ≤ 0.6 Others : ≤ 0.4
	36-45 %	≤ 0.49	≤ 0.55	≤ 1.90	≥ 1.00	North : ≤ 0.5 Others : ≤ 0.3

NR : No requirement.

For the minimum thermal resistance for low floors, the obligation is limited only to the slab-on-grade floors of air-conditioned or heated spaces.

Floor tiles should be insulated with thick insulation providing a thermal resistance as shown in the table. The low floors on piles exposed to the outside air will be treated as roofs.

3.2 Social economic, energy and environmental impacts expected from the thermal regulation

3.2.1. Administrative buildings

3.2.1.1. Impacts upon the establishment

• Impact on thermal heating and cooling requirements :

The thermal simulations show that gains in thermal requirements for heating and cooling in office buildings vary according to climatic zone from 52% to 74% compared with the reference base, as shown in the following charts :

Figure 32.
Comparison between basic case (BC) and thermal regulation (RT) : administrative building (T = 26 °C in summer) depending on climatic zone

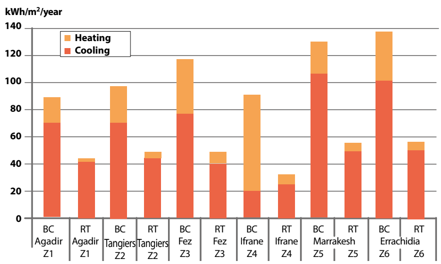
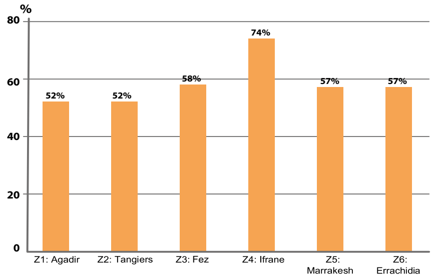


Figure 33.
Impact of thermal regulation on reducing the requirements for heating and cooling office buildings in Morocco (% reduction)

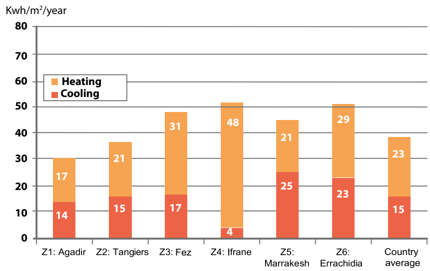


The largest gains are observed in cold areas like Ifrane and Fez.

• Impact on final energy consumption :

Taking into account the type of heating and cooling as well as yields on equipment use, the gain in final energy for offices varies, depending on the climatic zone, from 31 kWh/m²/year to 52 kWh/m²/year. Given the occupancy profile of the buildings, the savings in heating are the most important.

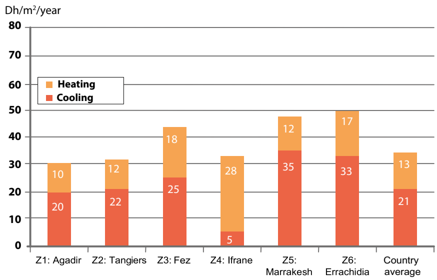
Figure 34.
Saving in final energy for heating and cooling depending on climatic zone : administrative buildings.



• Impact on the energy bill of the establishment :

Energy savings result in a substantial gain on the energy bill of the facility. It averages 34 Dh/m²/year and ranges from 30 to 50 Dh/m²/year according to the climatic zone.

Figure 35.
Gain on energy bills for consumers depending on climatic zone : administrative buildings.



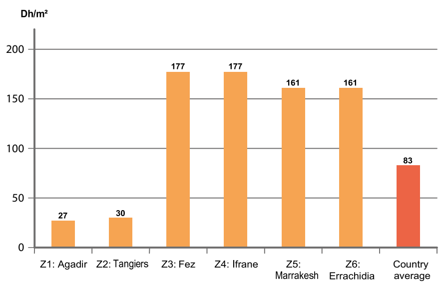
- **Additional cost implied by compliance with the regulation :**

The extra cost of thermal regulation in office buildings is on average 83 Dh/m², or about 1.3 %. This additional cost varies from 27 Dh/m² in the Z1 zone to 177 Dh/m² in areas of Ifrane and Fez, as shown in the charts below. In relative terms, these costs vary from 0.42 % to 2.72 % of the construction cost.

Table9.
Additional cost for administrative buildings in %

Z1	Agadir	0.42
Z2	Tangiers	0.46
Z3	Fez	2.72
Z4	Ifrane	2.62
Z5	Marrakesh	2.48
Z6	Errachidia	2.48

Figure 36.
Average additional investment costs implied by the thermal regulation according to the climatic zone : administration

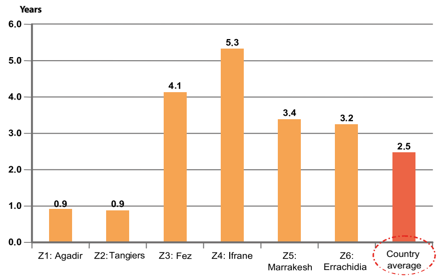


Profitability of the thermal regulation for the building:

The investment payback of the implementation of thermal regulation for the building is an average 2.5 years and varies, depending on the zone, from more than 1 year to 5 years in the Ifrane region.

Thermal regulation is profitable for administrative buildings, with few small constraints in Ifrane and Fez area.

Figure 37.
Payback time for the end user depending on the climatic zone : administrative building

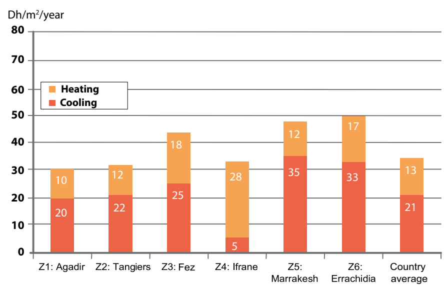


3.2.1.2. Impacts for the State and the community

- **Gain in primary energy**

The gain in primary energy is estimated to average 6 Kgoe/m²/year and varies depending on the zones from 4.5 to 8.5 Kgoe/m²/year. Because of the reduction due to air conditioning, the largest gains are obtained in warm areas of Marrakesh and Errachidia.

Figure 38.
Gain in primary energy according to climatic zone : administrative building

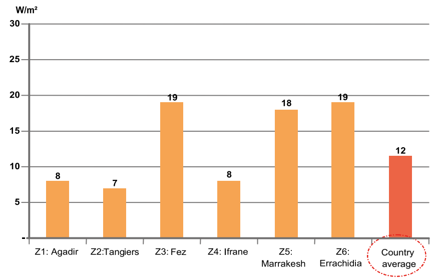


- **Gain in installed capacity :**

The application of thermal regulation results in a significant reduction in power demand for air conditioning. It is around 12 W/m².

The largest gains were observed in the climatic zone of Fez, Marrakesh and Errachidia, as shown in the chart below.

Figure 39.
Electrical power avoided according to climatic zone : administrative building



- **Avoided CO2 emissions:**

The CO_2 savings are estimated to average 16 kgeCO_2 per m² per year.

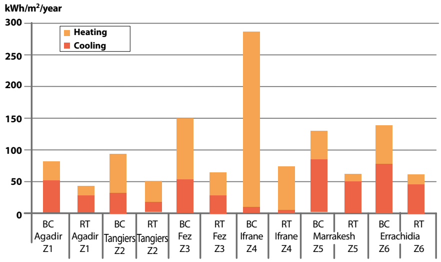
3.2.2. Schools

3.2.2.1. Impacts for the establishment

- **Impact on thermal requirements in heating and cooling :**

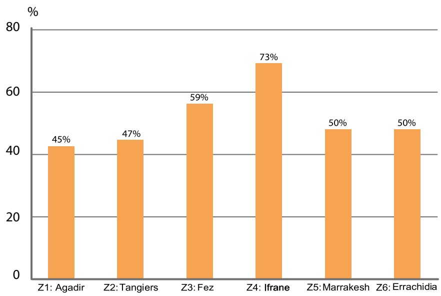
The gain in thermal requirements for heating and cooling in school buildings varies according to climatic zone from 45 % to 73 % compared to the reference base, as shown in the following charts :

Figure 40.
Comparison between base case (BC) and thermal regulation (RT) : school buildings (T = 26 °C in summer) depending on climatic zone



The largest gains are observed in cold areas like Ifrane and Fez.

Figure 41.
Impact of thermal regulation on reducing the requirement for heating and cooling school buildings (% reduction)



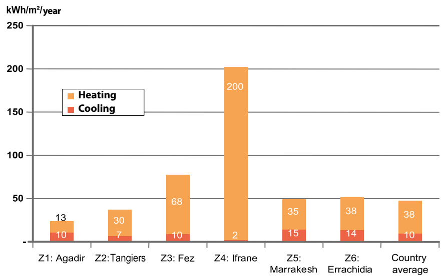
- **Impact on final energy consumption :**

Taking into account the type of heating and cooling as well as yields on equipment use, the gain in final energy for school buildings is on average 48 kWh/m²/year.

They range from 23 kWh/m²/year to 202 kWh/m²/year depending on the climatic zone.

Given the occupancy profile of these buildings the economies in heating are the most important.

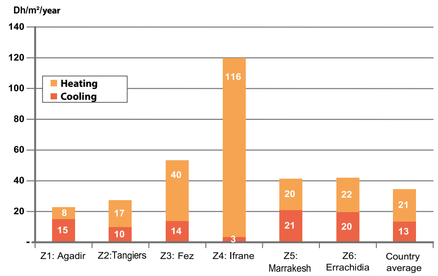
Figure 42.
Saving in final energy for heating and cooling depending on climatic zone : school buildings



• Impact on the energy bill of the building :

Energy savings result in a gain on the energy bill of the facility. It averages 34 Dh/m²/year and ranges from 23 to 119 Dh/m²/year depending on the zone.

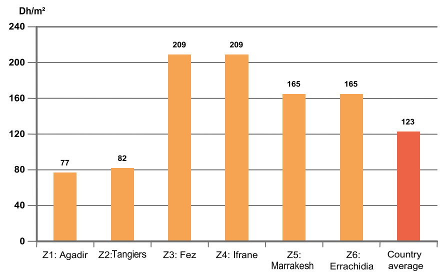
Figure 43.
Gain on energy bills for consumers depending on climatic zone : school buildings



• Additional costs implied by compliance with the regulation:

The extra cost of thermal regulation in schools is on average 128 Dh/m², or about 2.25 %. This additional cost varies from 77 Dh/m² in the Z1 zone to 209 Dh/m² in the zones of Ifrane and Fez, as shown in the graph below.

Figure 44.
Additional investment costs implied by the thermal regulation depending on climatic zone school buildings



In relative terms, these costs vary from 1.93 % to 5.23 % of the construction cost.

Table 1.
Additional costs for schools in %

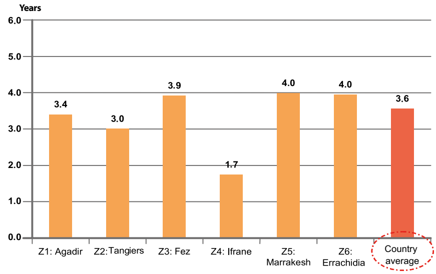
Z1	Agadir	1.93
Z2	Tangiers	2.05
Z3	Fez	5.23
Z4	Ifrane	5.23
Z5	Marrakesh	4.13
Z6	Errachidia	4.13

• Profitability of the thermal regulation for the building :

The investment payback of the application of thermal regulation for the school building is an average 3.6 years and ranges from 3.4 years in the zone Z1 to 4 years in Ifrane and Fez region.

Thermal regulation is cost-effective for school buildings and should be developed on a spontaneous support by the Ministry of Education.

Figure 45.
Payback time for the end user depending on the climatic zone : school buildings

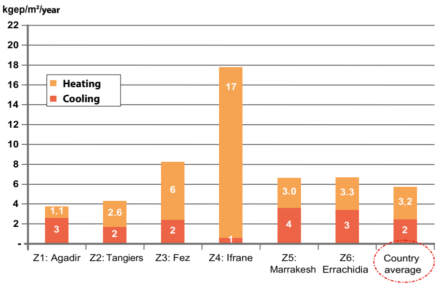


3.2.2.2. Impacts for the State and the community

- **Gain in primary energy :**

The gain in primary energy is estimated to average 5.2 Kgoe/m²/year and varies depending on the area from 4 to 18 Kgoe/m²/year. The largest gains are obtained in cold areas like Ifrane and Fez.

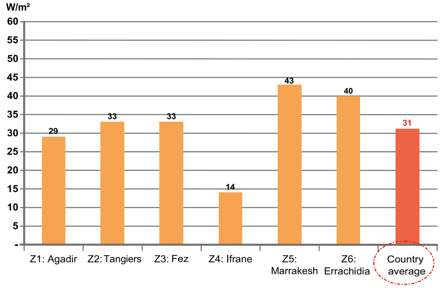
Figure 46.
Gain in primary energy according to climatic zone : school buildings



- **Gain in installed capacity :**

The reduction in power demand for air conditioning is around 31 W/m². The largest gains are observed in warmer climates in Marrakesh or Errachidia, as shown in the chart below.

Figure 47.
Electrical power avoided according to climatic zone : school buildings



- **Avoided CO2 :**

The CO_2 savings are estimated to average 16 kgeCO_2 per m² per year.

3.2.3. Hospital Buildings

3.2.3.1. Impacts for the establishment

- **Impact of the thermal requirements for heating and cooling ;**

The gain in thermal requirements for heating and air conditioning in the hospital buildings varies according to climatic zones from 40 % to 73 % compared with the reference base, as shown in the following charts :

Figure 48.
Comparison between basic case (BC) and thermal regulation (RT) in hospital building (Ti = 26 % in summer) depending on the climatic zone

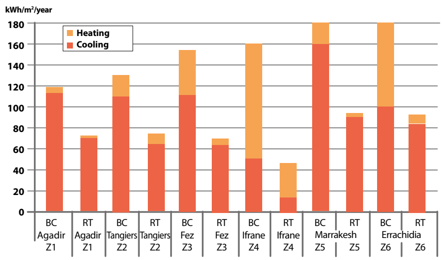
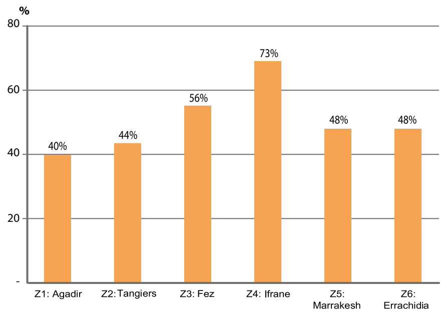


Figure 49.
Impact of the thermal regulation on reducing the requirement in heating and cooling for of hospital buildings in Morocco (% reduction)

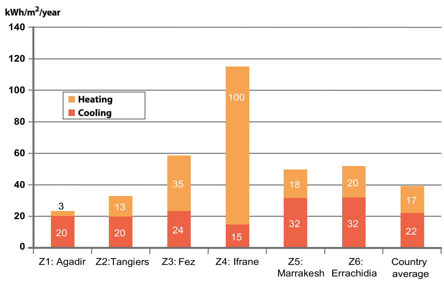


• Impact on final energy consumption :

Taking into account the type of heating and cooling as well as yields on equipment use, the gain in final energy for hospital buildings is on average 39 kWh/m²/year, of which 22 kWh for air conditioning.

This gain varies depending on climatic zone from 23 kWh/m²/year up to 115 kWh/m²/year in the zone represented by Ifrane

Figure 50.
Gains in final energy for heating and cooling depending on climatic zone : hospital building

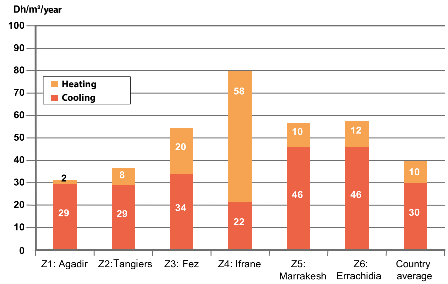


• Impact on the energy bill of the establishment :

Energy savings translate into significant gains in the facility energy costs. They average 40 Dh/m²/year.

These savings will vary depending on the area from 31 to 80 Dh/m²/year in the Ifrane zone.

Figure 51.
Gain on energy bills depending on climatic zone : hospital building

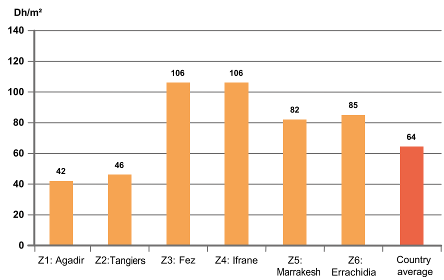


• Additional costs implied by compliance with the regulation :

The extra cost of thermal regulation in hospital buildings is in average 64 Dh/m² or about 1.72 %.

This additional cost is between 42 Dh/m² in the Z1 zone to 106 Dh/m² in areas of Ifrane and Fez, as shown in the chart below.

Figure 52.
Additional average investment costs implied by the thermal regulation depending on climatic zone : hospital building



In relative terms, these costs vary from 1.05 % to 2.65 % of the construction cost.

Table 1.
Additional costs for hospitals in %

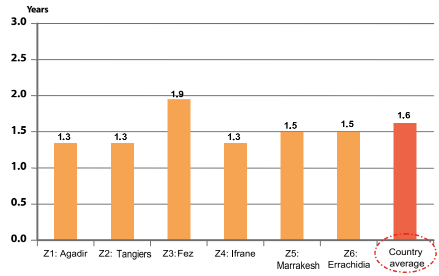
Z1	Agadir	1.05
Z2	Tangiers	1.15
Z3	Fez	2.65
Z4	Ifrane	2.65
Z5	Marrakesh	2.05
Z6	Errachidia	2.05

• **Profitability of thermal regulation for the building** :

The investment payback of the application of thermal regulation for the hospital is in average 1.6 years and varies depending on the area from 1.3 years to 1.9 years in the Fez region.

Thermal regulation is very profitable for hospitals and should develop on a purely commercial basis.

Figure 53.
Payback time for the end user depending on the climatic zone : hospital building

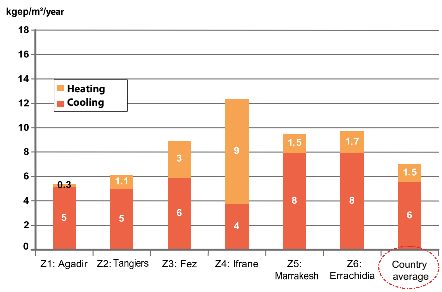


3 .2.3.2. Impacts for the State and the Community

• **Gain in primary energy :**

The gain in primary energy is estimated to average 7.5 Kgoe/m²/year and varies depending on the area from 5to13 Kgoe/m²/year in the Ifrane zone.

Figure 54.
Gain in primary energy according to climatic zone : hospital building

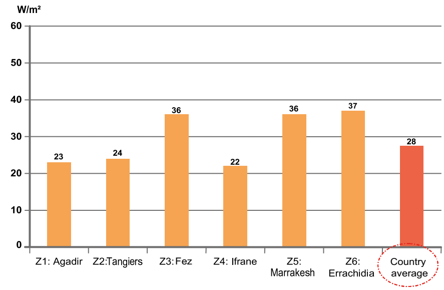


• **Gain in installed capacity :**

The application of the thermal regulation translates into a significant reduction in power demand for air conditioning. It is around 28 W/m².

The largest gains were observed in the climatic zone of Fez, Marrakesh and Errachidia, as shown in the chart below.

Figure 55.
Electrical power avoided according to the climatic zone : hospital building



• **Avoided CO_2 :**

The CO_2 savings are estimated to average 20 kgeCO_2 per m² per year.

3 .2.4. Hotel establishments

3 .2.4.1. Impacts for the establishment

• **Impact on thermal requirements in heating and cooling :**

The gain in thermal requirements for heating and air conditioning in hotels varies in function of climatic zone from 46 % to 70 % compared to the reference base, as shown in the following chartss :

Figure 56.

Comparison between basic case (BC) and thermal regulation (RT) : hotels (Ti = 26 % in summer) depending on the climatic zone

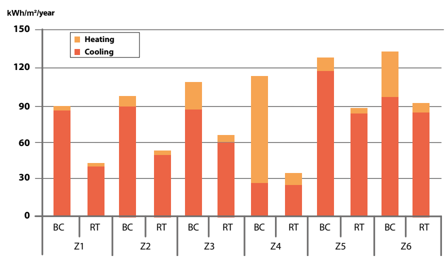
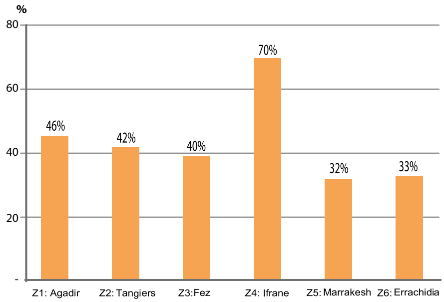


Figure 57.
Impact of thermal regulation on reducing the requirement for heating and cooling of hotels (% reduction)



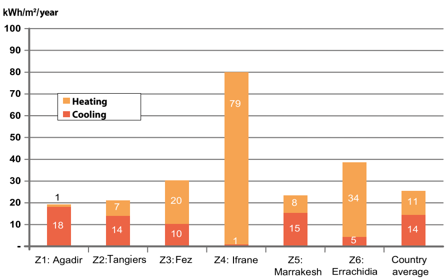
The largest gains are observed in cold areas like Ifrane.

- **Impact on final energy consumption :**

Taking into account the type of heating and cooling and the performance of user equipment, the gain in final energy for hotels is in average 25 kWh/m²/year.

It varies depending on the climatic zone from 19 kWh/m²/year to 80 kWh/m²/year.

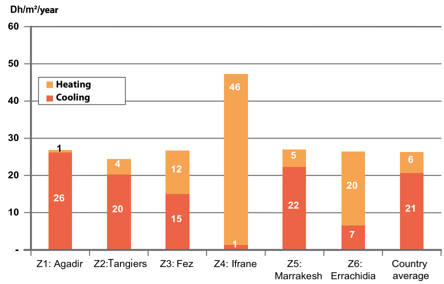
Figure 58.
Gains in final energy for heating and cooling depending on climatic zone : hotels



- **Impact on the energy bill of the facility :**

Energy savings translate into a gain on the energy bill. It averages 27 Dh/m²/year and can reach up to 47 Dh/m²/year depending on the zone.

Figure 59.
Gains on energy bills depending on climatic zone : hotels

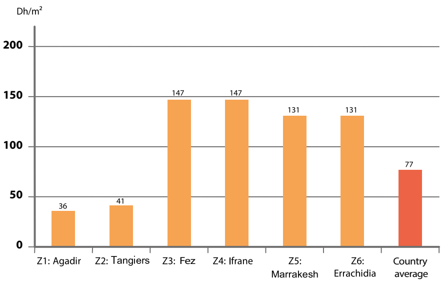


- **Additional costs implied by compliance with the regulation :**

The extra cost of thermal regulation in hotels is on average 77 Dh/m² or about 1.36 %.

This additional cost ranges from 36 Dh/m² in the Z1 zone to 147 Dh/m² in areas of Ifrane and Fez, as shown in the chart below.

Figure 60.
Additional investment costs implied by the thermal regulation according to climatic zone hotels



In relative terms, this additional cost ranges from 0.45 % to 1.85 % of the construction cost.

Table 12
Additional costs for hotels in %

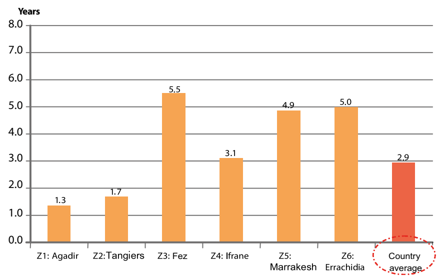
Z1	Agadir	0.45
Z2	Tangiers	0.52
Z3	Fez	1.85
Z4	Ifrane	1.85
Z5	Marrakesh	1.65
Z6	Errachidia	1.65

- **Profitability of the thermal regulation for the establishment :**

The investment payback of the application of thermal regulation is in average 2.9 years and varies depending on the area from 1.3 years in the coastal area to nearly 5 years in the region of Fez, Marrakesh and Errachidia. Thermal regulation is profitable for the hospitality industry and should be developed based on market mechanisms.

Figure 61.

Payback time for the end user depending on the climatic zone : hotels



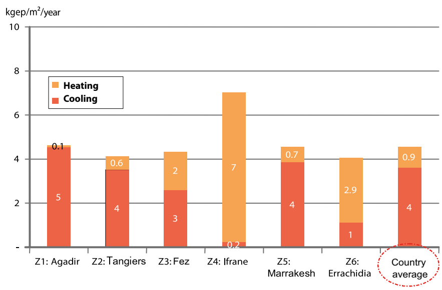
3.2.4.2. Impacts for the State and the community

- **Gain in primary energy :**

The gain in primary energy is estimated to average 4.9 Kgoe/m2/year and ranges from 3.9 to 7.2 Kgoe/m2/year depending on the climatic zone..

Figure 62.

Investment payback depending on the climatic zone : hotels

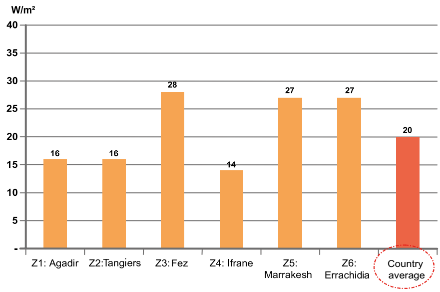


- **Gain in installed capacity :**

The reduction in power demand for air conditioning is about 20 W/m². The largest gains are observed in areas of Marrakesh, Fez and Errachidia, as shown in the chart below.

Figure 63.

Gain in energy source according to climatic zone : hotels



- **Gains in CO_2 emissions :**

The avoided CO_2 emissions are estimated to average 13 kgeCO_2 per m² per year.

Conclusion 4

4

CONCLUSION

The requirements of the Thermal Regulation of Construction in Morocco are a compromise between the reduction in thermal requirements of the target buildings and the extra investment implied by technical measures for implementing regulatory specifications.

These specifications were developed through a process of technical and policy dialogue with stakeholders, especially public institutions, namely the ministries in charge of housing, tourism, public health, education, finance and energy.

Thermal regulation is economically feasible for most final consumers in several sectors. Indeed, the additional costs are usually absorbed by the construction market, provided that their profitability for the end consumers is taken into account.

However application constraints may remain for the specific segment of social housing over much of the Moroccan territory, given the relative importance of costs. Indeed, for this segment, the profitability of required measures remains low, limiting the attractiveness of thermal regulation vis-à-vis this category of low-income households.

For this, it seems essential that for this specific segment of buildings, the implementation of the regulation, at least at the beginning of its application, is aided by public financial support whose target is to decrease the investment payback down to sufficiently attractive levels for this category of consumers.

This public support remains « profitable » for the State and the Moroccan Community, considering the positive effects of the regulation in terms of public subsidies avoided in conventional energies, the investment gains in the construction of the additional capacities of electric production, the reduction of the energy bill of the country, the creation of employment, etc.

The mechanisms and procedures for implementation of this public financial support should be further defined in detail.

Finally, it is important to emphasize the requirement to support the implementation of thermal regulation with a plan of action to facilitate its setting up by removing market barriers, such as :

- actors training in implementation : designers, operators, businesses, artisans,...
- communication and sensitization of policy makers and the general public ;
- development support of the supply of materials and services related to the implementation of the regulation technical measures...
- development of specific funding mechanisms (dedicated credit lines, tax exemptions....).

APPENDIX : GLOSSARY OF ABBREVIATIONS AND TECHNICAL TERMS

Table 13.
List of Abbreviations

ADEREE	National Agency for the Development of Renewable Energy and Energy Efficiency.
HVAC	Heating, Ventilation and Air Conditioning.
DNM	Directorate of National Meteorology.
CDD	Cooling degree-days.
HDD	Heating degree days.
EE	Energy Efficiency.
GIZ	German cooperation.
LPG	Liquefied petroleum gas.
Kgoe	Kilogram of oil equivalent.
UNDP	United Nations Programme for Development.
TRCM	Thermal Regulation of Construction in Morocco.
$TeCO_2$	CO_2 equivalent ton.

Table 14.
Glossary of abbreviations and Technical terms

Parameters	Symbol	Definition	Unit
Thermal transmission coefficient	U	The thermal transmission coefficient of a wall is noted "U" (or formerly "K") and characterizes the amount of heat passing in a permanent regime through a wall, per unit of time, per unit of area and per unit of temperature difference between environments situated on either side of said wall.	W/m2.K
Thermal Résistance	R	Unlike the heat transfer coefficient.	$m^2.K/W$
Solar factor	SF	The solar factor (also called Solar Heat Gain Coefficient, SHGC) is the amount of solar energy as a percentage (%), found behind the windows exposed to sunlight (without sunscreens external and internal).	-
Solar factor equivalent	SF*	The equivalent solar factor of picture windows is the amount of solar energy as a percentage (%), found behind them associated with their architectural outdoor shading.	-
Picture windows global rate	PWGR	The ratio of the total windows surface (including frames) to the total gross surfaces of external walls.	-
Thermal conductivity	λ	The amount of heat transferred per unit area of a material.	$W/m^2.K$

Thermal Regulation of Construction in Morocco (TRCM) Simplified version

amee
Moroccan Agency for Energy Efficiency