ENERGY AUDIT OF THE PALACE OF BELÉM

Summary Report

OFFICIAL RESIDENCE OF THE PRESIDENT OF THE REPUBLIC

PALACE OF BELÉM

2007

Executive Summary

Global energy description and analysis

This Energy Audit had as its main objective the energy description of the Official Residence of the President of the Republic, the Palace of Belém, as to the thermal quality of the buildings and of their energy systems, and to gather information which could allow specifying energy economy as a result of **Energy Efficiency** and the **Rational Use of Energy**, which would induce reduction, not just of energy consumed and respective costs, but also the emission of greenhouse gases – carbon dioxide (CO_2).

The Palace of Belém, Official Residence of the President of the Republic, including the General Secretariat of the Presidency, Civil Office and Military Office, Documentary and Information Centre, Museum of the Presidency and respective auxiliary buildings, located in Lisbon (Belém), cover an area of approximately four hectares.

The institution consumed during the reference period of this work (May 2006 to April 2007) a total of 1.46 GWh of electrical energy, corresponding to 424 toe, which, in terms of CO_2 emissions to the atmosphere, is equivalent to approximately 643 ton CO_2 equiv/year.

Costs in the reference period amounted to 127,131 €.

As to the use of electrical energy per department/equipment, the greatest users were those installed in the switchboard supplying the Documentary and Information Centre (DIC), accounting for 23.9% of energy consumed. Switchboards of Palace Tunnel 1 and Tunnel 2 account for respectively 13.3% and 15.9% of energy consumed. The switchboard in the Annex to the Palace building accounted for 15.6%, whilst that of the General Secretariat 9.4%, the Museum 4.3% and that of the Porter's Lodge 3.2%, and the Computer Centre 2.2%. Other sundry usages account for 12% of the total energy consumed.

As to electrical power by sector, 40% relates to lighting, 35% to air conditioning and the remaining 25% to power point circuits (including computer equipment).

Thermal energy in the Palace of Belém (natural gas and diesel oil) is consumed in boilers and kitchen equipment. Two solar panels support the sanitary hot water system.

The supply of natural gas to the Palace of Belém is provided by the "Lisboa Gás" Distribution Network of Natural Gas, in a Low Pressure system with three delivery points located in: Calçada da Ajuda, Rua da Junqueira and Travessa dos Ferreiros.

Diesel oil supply is ensured by two fuel tanks installed in the Palace of Belém.

Thermal energy consumed in the reference period was 47 toe which, in terms of CO_2 emissions to the atmosphere corresponds to 123 tonnes CO_2 equivalent. Natural gas consumed during the reference period amounted to 32,528 m^3, at a cost of 18,175 €; diesel oil consumed amounted to 20,200 l, at a cost of 11,618 €.

In global terms – thermal and electric energy – the institution consumed 471 toe, corresponding to an emission of 771 tonnes of CO_2 eq, at a total cost of 156,924 €.

Identification of opportunities for improvement and issue of proposals

This Energy Audit was a means to identify possibilities to increase the energy efficiency of the institution's facilities, as follows:

- **Inclusion of Renewable Energies**

The Palace already has two independent systems to supply sanitary hot water, for which some simple measures are now proposed, related to their insertion into the conventional heating system, which will allow the improvement of its global performance.

Other areas were found where new renewable energy systems could be applied, such as:

1) the canteen located in building DIC, where hot water usage can be reduced by 75% with the installation of a thermal solar system with a 50 m^2 collection area;

2) a photovoltaic solar system with the same area (50m^2) with 5kWp power, to equally be installed on the roof of the DIC building;

3) The existing swimming pool could equally reduce energy usage through the installation of a surface cover for night use.

- **Electric Energy**

  - Increase in energy efficiency in the HVAC Section (**H**eating, **V**entilation and **A**ir **C**onditioning).
  - Increase in energy efficiency in the lighting sector,
  - Review of the electrical energy tariffs,
  - Residual and night usages,
  - Usage Management System,
  - Carrying out sensitizing campaigns for the rational usage of energy.

  In global terms the measures for the Rational Usage of Electrical Energy provide an annual reduction of approximately 447,000 kWh (130 toe, 196,5 tonnes CO_2 eq.), which is equivalent to a decrease in costs of 50,840 € (including the Tariff review); the investment required for the implementation of these measures is estimated at 95,000 €, equivalent to a 1.9 year payback period.

Thermal Energy

The institution uses natural gas and diesel oil as fuels for the production of thermal energy and also has two solar panels which complement the production of sanitary hot water. The energy characteristics of the main thermal energy production equipment was analysed, and the following measures proposed:

- Rectify the natural gas boilers:
  It is estimated that an annual economy in natural gas of 2,660m^3(n) will be achieved, corresponding to 28,009 kWh, or 2.4 toe, and equivalent to approximately 1,200 €/year. There will be a 5,666 kg annual CO_2 reduction. This alteration has no costs, and will be covered by the regular maintenance of the equipment.
  Attention is also called to the high values of diffusion of organic volatile compounds (OVC) from the “RocaG40” boiler, located in the Old Garage, which requires urgent refurbishment for reasons of security.
- Disconnect the thermal accumulators during week-ends:
  It is estimated that an annual economy in natural gas of 793m^3(n) will be achieved, corresponding to 8,350 kWh, or 0.72 toe/year, and equivalent to approximately 357 €/year. This alteration has no costs. Annual reduction in CO_2 will be 1,690 kg.
- Insulate the tubing of the boiler plant in the Palace kitchen:
  The insulation of the hot water pipes located in the boiler plant of the residence will allow an economy of 3,775 kWh, equivalent to 470 kg toe/year, corresponding to an annual economy of 346 €. Annual reduction in CO_2 will be 1,417 kg. The estimated cost for this operation is 140 €.

Since the conversion of the use of diesel oil to natural gas is now technically viable, a further opportunity exists to improve the efficiency of the system, decreasing contaminating emissions and lowering operational costs. As a complement to the new natural gas system, advantages would also arise from the optimization/expansion of the solar panels, with the objective to improve the efficiency of the hot water production system. Implementing an integrated natural gas/solar thermal system for the production of hot waters should also be considered in the DIC canteen.

- The estimated investment for change from diesel oil to natural gas is 39,978 €, which would result in an annual economy of 5,376 €, corresponding to a 20% reduction in fuel operational costs, and to a payback period of 7.5 years;
- In case the natural gas/solar thermal system is adopted, the required investment would be 55,978 €, resulting in an annual economy of 6,550.45 €, corresponding to a 20% reduction in fuel operational costs and to a payback period of 8.6 years;
- The conversion of the total usage of diesel oil to natural gas would result in 15 tonnes/year reduction in CO_2 emissions;
- The adoption of an integrated natural gas/solar thermal system would result in an approximately 25 tonnes/year reduction in CO_2 emissions;
- Lastly, a proper maintenance of all the installed and to be installed systems is required, in order for their output to be maximized.

Analysis of the safety conditions of the electric power facilities

The electric power facilities in the various buildings of the Palace of Belém were subject to a technical assessment. This work consisted specifically in the appraisal of the final circuits, switchboards, transformer and respective emergency generator.

This assessment identified some instances of non compliance with the applicable electrical regulations, especially the lack of protection from direct contacts, indirect contacts, lack of continuity of the grounding cables, lack of differential protection (medium and high) and incorrect protection of the circuits which compromise personal and/or user safety and, directly, the status of the operation of the electric power installations, which can cause eventual short circuits or overloads which could seriously damage the facilities and be the origin of possible damages (e.g., fire risk). It was also found that there were no up to date plans with the location of the switchboards and their feeder network.

Analysis of the safety conditions of the gas facilities

In compliance with the legislation currently in force, a survey was carried out to the visible portions of the Natural Gas facilities of the Palace of Belém by an official Inspection Body – the Institute for Gas Technology (IGT). In accordance with this Institution's report several instances were encountered, which must be subject to correction, as follows:

Travessa dos Ferreiros delivery point

- Replace the exhaust tubes of the bathhouse boilers, which are located below the air intakes of the adjacent buildings.

Rua da Junqueira delivery point

- The gas facilities of the Staff Quarters, downstream from the metering group, must not be fastened to wooden walls; the switching valves on the outside of the buildings are not accessible.

- The Laundry gas facilities cross the sanitary installations, thus not complying with the provisions of item b) of §3 of art. 16 of Ordinance 361/98 dated June 26.

- The Museum boilers are inside a closed cupboard. .

In order to assess the situation of the whole installation, it is necessary to carry out sealing tests and to check the conditions of ventilation and exhaust of the products from combustion, for the purpose of which the Palace of Belém must request a Periodical Inspection to its gas facilities which, in accordance with Ordinance No. 362/2000, dated June 20, must be carried out in line with the provisions of art. 13 of Decree-Law No. 521/99, dated December 10, once every two years, for gas facilities pertaining to the tourist and restaurant industry, schools, hospitals and other health services, barracks and any public or private establishments with a capacity exceeding 250 persons.

Thermal analysis of the buildings

The conditions of thermal comfort in the main buildings of the Palace of Belém were monitored in 18 separate areas, generally resulting in an acceptable thermal behaviour, requiring however that some situations should be subject to restoration. Areas to be considered included the reinforcement of thermal insulation in the roofs of some of the buildings, the possibility of altering some of the window frames (already being carried out in some cases), and the alteration of the external shadowing of the spans to the east of the DIC, as a means to avoid temperature peaks during the mornings periods.

Classifications in the terms of energy classes, within the scope of Energy Certification of Buildings are proposed, with the following classifications:

Palace of Belém and Official Residence of the President of the Republic – CLASS C
Civil and Military Offices – CLASS B-
Documentation and Information Centre – CLASS B

edp corporate

INETI

galp energia

Certificação Energética e Ar Interior EDIFÍCIOS

NATIONAL SYSTEM OF ENERGY CERTIFICATION AND OF THE INTERNAL AIR QUALITY IN BUILDINGS

Certificate of energy performance and internal air quality

No. CER12345679/year

Type of building:	**PALACIO OF BELÉM**		
Address / Situation:	Calçada da Ajuda, 11		
Location:	1349-022 Lisboa	**Parish:**	Ajuda
County:	Lisbon	**Region:**	Lisbon
Date of issue of certificate:	July 1, 2007	**Validity of certificate:**	
Name of the qualified expert:	INETI	**Number of the qualified expert:**	
Building described	**Registry of Buildings of**		
under No.	**Registration No.**	**Autonomous Building**	

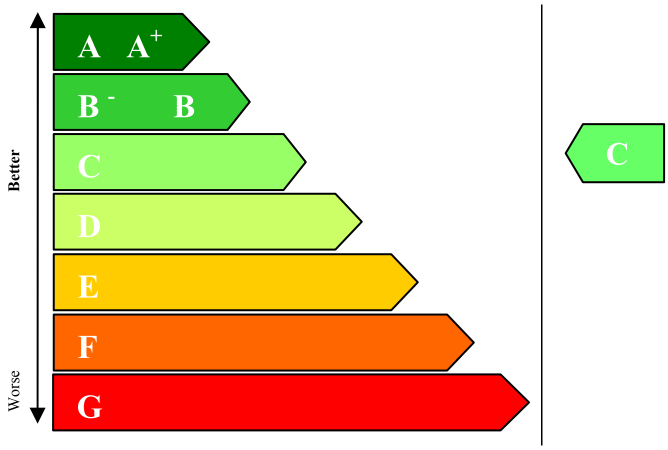
This certificate results from a check carried out in the building or autonomous part by a duly qualified expert, relative to the requisites provided for in the Regulations for the Thermal Behaviour of Buildings (RCCTE, Decree-Law 80/2006 dated April 4), classifying the building with respect to its respective energy performance. This certificate may include possible measures to improve performance applicable to the building or autonomous part, its components and respective energy and ventilation systems, whether in the case of energy performance or in that of internal quality of air.

1. Label of energy performance

PERFORMANCE INDICES

Estimated annual global requirements of usable energy for air conditioning and hot waters	101	kWh/m^2.year
Estimated annual global requirements of primary energy for air conditioning and hot waters	1.20	kgep/m^2.year
Maximum regulated value for the annual global requirements of primary energy for air conditioning and hot waters	0.94	kgep/m^2.year
Annual hothouse gas emissions related to primary energy for air conditioning and hot waters	3.698*	tonne of CO_2 equivalent per year

ENERGY CLASS



*Conversion factor used 0.0012 tonnes CO_2/kgep/m^2

Figure 1- Example of a model of an energy certificate.

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1 INTRODUCTION

1.1 Scope

The Audit covers the **energy efficiency of the buildings** regarding lighting, air conditioning, thermal performance and heating of sanitary hot waters, as well as the **safety of the gas and electric power facilities**. In addition to **identifying the weaknesses** of the building in terms of efficiency and energy safety, the audit makes **proposals** aiming to correct the identified issues.

1.2 Objectives

This Energy Audit had as its main objective the assessment of the energy characteristics of the Official Residence of the President of the Republic, the Palace of Belém, as to the thermal quality of the buildings and their energy systems, and to obtain data allowing the measurement of the energy economies obtainable in terms of Energy Efficiency and Rational Usage of Energy, which would influence reductions, not just in energy usage and respective costs, but also in greenhouse gas emissions – carbon dioxide (CO_2).

A further objective of this task is the analysis of the internal environment in the various buildings, which involves determining the concentration of gases, particles, bacteria and fungi in the internal air, as well as determining in various surfaces the presence of *Legionella sp.*

1.3 Methodology

The methodology followed was based on the terms of reference provided by the Civil Office of the President of the Republic and included the following stages:

- Listing of existing information;
- Carrying out field work in the consuming institution;
- Preparation of the Final Report of the Energy Audit;

The Final Report of the Energy Audit consists of:

- Summary Report of the results achieved with the Audit and proposals issued, including an Executive Summary.
- Partial reports and respective enclosures prepared by the three institutions that took part in the Audit (INETI, EDP and GALP).
- Addendum containing the results of the Internal Air Quality.

The audit was carried out in a partnership system, between **INETI, EDP and GALP,** with the following task distribution:

INETI Team

- Thermal Characteristics of the Buildings (Palace and Residence, Civil and Military Offices, Documentation and Information Centre)
- Assessment of the Thermal Performance of the Building and respective conditions of Thermal Comfort.
- Details of the existing renewable energy systems.
- Details of the equipments using Natural Gas and Diesel Oil and definition of emissions.
- Identification of opportunities to integrate renewable energies (Solar Thermal and Solar Photovoltaic).
- Thermal simulation to estimate future energy certification of the building.

EDP Team

- Description of the usage of electric energy in the buildings.
- Analysis of the environmental operating conditions of the building.
- Identification of opportunities to rationalize the usages of electric energy;
- Analysis of the safety conditions of the electric energy facilities.

GALP Team

- Description of the usage of natural gas and diesel oil.
- Identification of opportunities to rationalize the usages of natural gas and diesel oil.
- Analysis of the safety conditions of the gas facilities.

2 ENERGY CHARACTERISTICS OF THE BUILDINGS

The Official Residence of the President of the Republic, the Palace of Belém, including the General Secretariat of the Presidency, Civil Office, Military Office, Documentation and Information Centre, Museum of the Presidency and respective auxiliary buildings, are located in Lisbon (Belém) and cover an area of approximately four hectares.

The following table shows the usable areas considered for each building.

Table 1- Usable area per building

Building	**Area (m^2)**
Civil and Military Offices	1 950
Republican Guard	350
Museum Shop	340
Palace	3000
Security Police	1 100
Residencies/Laundry	680
General Secretariat	3 189
Old Garage	2 000
Museum	1 740
DIC	3 600
Total covered area	**17 950**

During the reference period of this work (May 2006 to April 2007) the institution consumed a **total of 471 toe**, of which 424 toe correspond to Electric energy and 47 toe to Natural Gas and Diesel Oil, thus a specific energy usage of **16.08 kgeo/m^2**.

The total cost of this energy was **156,924 €** (127,131 € for electric energy and 29,793 € for Natural Gas and Diesel Oil).

This energy usage is equivalent, in terms of $C0_2$ emissions to the atmosphere, to approximately **771 ton CO_2 eq/year**.

These usages are in accordance with the thermal performance of the existing buildings which is disparate due to the diversity of the buildings, built in different times with different materials and with differing uses, with energy usage linked to lighting and air conditioning and to the usage of equipment installed in the building complex, especially computing, communication and data treatment, etc.

The following paragraphs approach the characteristics of the energy usages obtained in the complex of the Palace of Belém, specifically in terms of three main themes: thermal performance of the buildings, usages of electric energy and usages of natural gas and diesel oil. The use of the currently existing renewable energy systems is equally approached.

2.1 Thermal Analysis of Buildings

The objective of this part of the Energy Audit of the Palace of Belém are the architectural and construction characteristics of the buildings which constitute the complex of the Palace of Belém, with the aim to determine the respective operational thermal conditions and the energy characteristics of the buildings. Also assessed are the internal thermal conditions through the measurement of the temperature of the dry bulb and of relative humidity and the identification of opportunities to improve the thermal quality of the building.

The appraisal of the energy performance of the Palace of Belém and Residence, Civil and Military Offices and of the Documentation and Information Centre is based upon the methodology adopted by the new energy regulation of buildings, specifically the Regulation of the Characteristics of Thermal Performance of Buildings (RCCTE, Decree-Law No. 80/2006, dated April 4) and the Regulation of the Energy and Air Conditioning Systems of Buildings (Decree-Law 79/2006 dated April 4).

The 2006 RCCTE endeavours to interpret the global energy efficiency of a building through four fundamental numerical indicators or thermal indices, which are the nominal energy requirements for: heating (Nic), cooling (Nvc), production of sanitary hot waters (Nac) and also primary energy (Ntc).

In addition to those fundamental thermal indices and also in accordance with Article 4, the characterization of the thermal performance is also carried out based on quantifying complementary parameters under specific conditions: superficial and linear coefficients of thermal transmission of the surrounding elements, the inertia class of the building or its autonomous part, the solar factor of the window spans and the rate of air renewal.

It should be pointed out that the methodology adopted by the RCCTE accounts for the concept and location relative to climatic conditions, alignment and influence of neighbouring buildings and structures, and also the technical characteristics of the equipment for the production of sanitary hot waters and environmental air conditioning.

The Energy Efficiency Classification is determined by the ratio between the nominal global requirements of primary energy Ntc of a building and the limiting value Nti, estimated from Ni, Nv and Na values.

In the case of RSECE an Indicator of Energy Efficiency (IEE) is calculated, which quantifies the nominal usages of a services building (kgep/m^2), and this result cannot exceed a certain value, obtained as a function of the type of building and its use(nominalIEE < referenceIEE).

Table 2 shows the different classifications and the respective intervals for new buildings and for those existing in the case of RCCTE.

RCCTE - Classes of Energy Efficiency for New and Existing Buildings.

Table 2 – RCCTE – Classes of Energy Efficiency

Existing Buildings (A+ to G) — New Buildings (A+ to B-)

Class	$R = \frac{N_{tc}}{N_t}$
A+	R ≤ 0,25
A	0,25 < R ≤ 0,50
B	0,50 < R ≤ 0,75
B-	0,75 < R ≤ 1,00
C	1,00 < R ≤ 1,50
D	1,50 < R ≤ 2,00
E	2,00 < R ≤ 2,50
F	2,50 < R ≤ 3,00
G	R < 3,00

The Class of Energy Efficiency was obtained for the Palace and Official Residence, Civil and Military Offices and Documentation and Information Centre.

External climatic conditions and those inside the buildings were monitored to assess the thermal performance and respective conditions of thermal comfort.

The equipment used during the reference period to obtain the characteristics of the external parameters were a meteorological plant consisting of a pyranometer to measure the horizontal solar radiation, a temperature and humidity probe and an integrated transducer to measure the intensity and direction of the wind.

To obtain data relative to the internal environment a mini data-logger was used, with internal sensors for temperature and humidity.

The records of the various parameters, radiation, temperature and relative humidity were registered at 60 minute intervals.

This set of sensors allowed obtaining the movement of temperatures throughout May 2007 and to assess the average of maximum and minimum temperatures, and compare these with the meteorological station located externally. It should be pointed out that the analysed month (May) corresponds to a transitional period, and as such an assessment of extreme conditions should be carried out taking measures both during a summer month and a winter month.

Average external data during this period is shown in Table 3.

Table 3 – External Climate – May 2007

Global radiation [kW/m^2]	Temperature [ºC]		
	Minimum averages	Maximum averages	Average
190,9	14,0	21,7	17,6

The results obtained for each of the analysed buildings in the Palace of Belém complex are as follows:

PALACE OF BELÉM AND RESIDENCY

Table 4 shows measurements obtained during the month of May.

Table 4 – Internal and external temperatures

Location	Temperature [ºC]		
	Minimum averages	Maximum averages	Average
Presidential Office	22,1	25,1	23,7
Reception Hall	21,6	24,7	23,0
Dining Room	21,2	22,8	21,9
Empire Hall	21,6	23,9	22,6
External	14,0	21,7	17,6

Following is an example of the results of the measurements carried out in the Palace of Belém in the areas: Presidential Office, Reception Hall, Dining Room and Empire Hall.

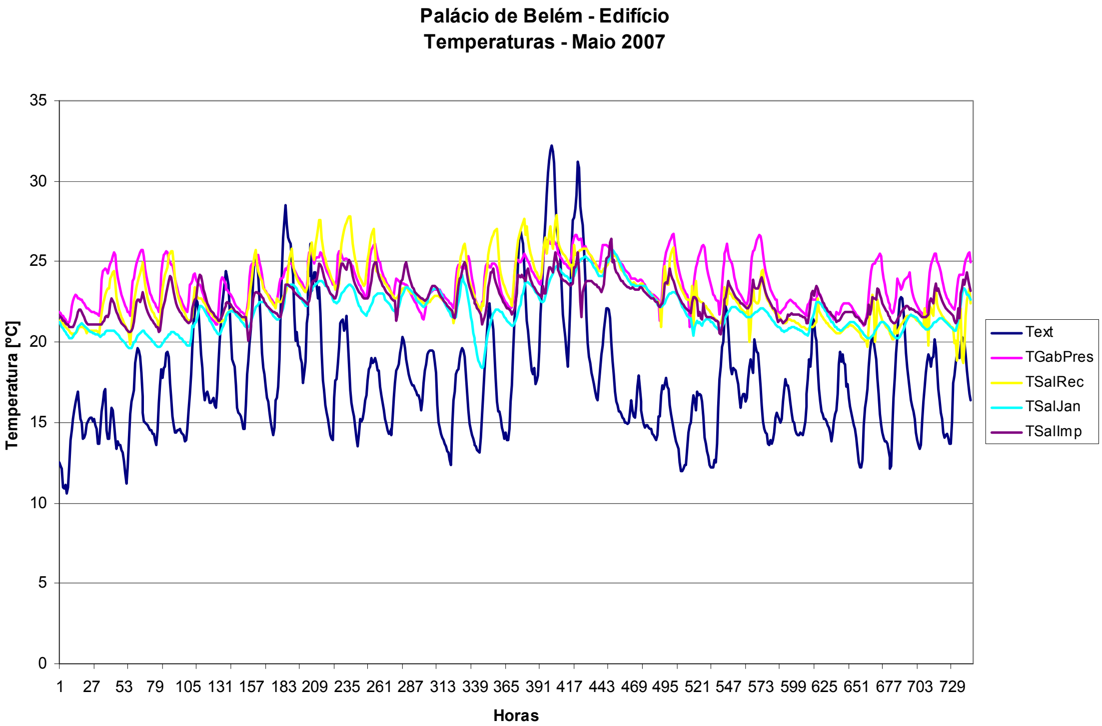


Figure 2 – Temperatures measured inside the Palace and external temperatures.

In regulatory terms the following results were obtained through the application of RCTTE to the **Palace and Official Residence**.

Table 5 – Energy Indices for the Palace and Official Residence

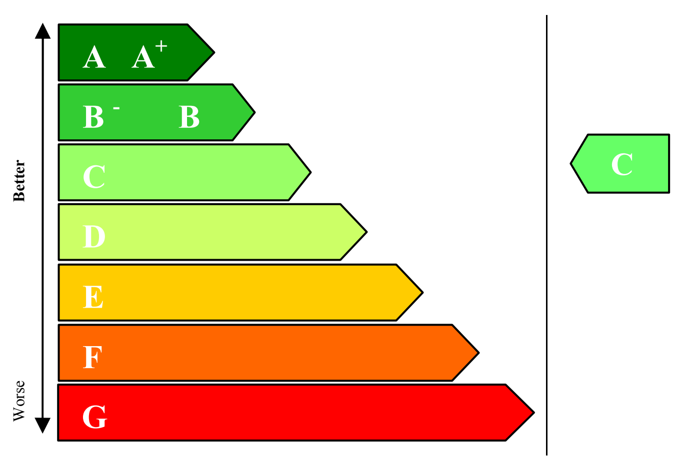
Current Construction
Heating Requirements: Nic ≤ Ni (Article 5)
88.9 (kWh/ m^2.year) ≤ 51.51 (kWh/ m^2.year)
Cooling Requirements: Nvc ≤ Nv (Article 6).
12.3 (kWh/ m^2.year) ≤ 32.00 (kWh/ m^2.year)
Hot Water Requirements: Nac ≤ Na (Article 7).
0.43 (kWh/ m^2.year) ≤ 1.38 (kWh/ m^2.year)
Total Requirements of Primary Energy: Ntc ≤ Nt (Article 8)
1.20 (kgep/m^2·year) ≤ 0.94 (kgep/m^2.year)

As already referred a class C energy classification corresponds to these conditions.

1. Label of energy performance

PERFORMANCE INDICES		
Estimated annual global requirements of usable energy for air conditioning and hot waters	101	kWh/m^2.year
Estimated annual global requirements of primary energy for air conditioning and hot waters	1.20	kgep/m^2.year
Maximum regulated value for the annual global requirements of primary energy for air conditioning and hot waters	0.94	kgep/m^2.year
Annual greenhouse gas emissions related to primary energy for air conditioning and hot waters	3.698*	tonne of CO_2 equivalent per year

ENERGY CLASS



*Conversion factor used 0.0012 tonnes CO_2/kgep/m^2

Figure 3- Example of a model of an energy certificate – Palace of Belém and Official Residence

CIVIL AND MILITARY OFFICES

The thermal performance of the building was carried out in 4 different areas with the following results of temperature measurements:

Table 6 – Internal and external temperatures

Salas	Temperature [ºC]		
	Minimum averages	Maximum averages	Average
Mrs. Cavaco Silva's Office	22,6	23,8	23,3
Meeting Room	21,4	22,2	21,7
Dr. J. Moreira da Silva' Office	22,1	23,6	22,7
North Office	20,5	22,7	21,4

Figure 4 shows the hourly movement of the internal air temperature for the 4 monitored rooms and the external air temperature.

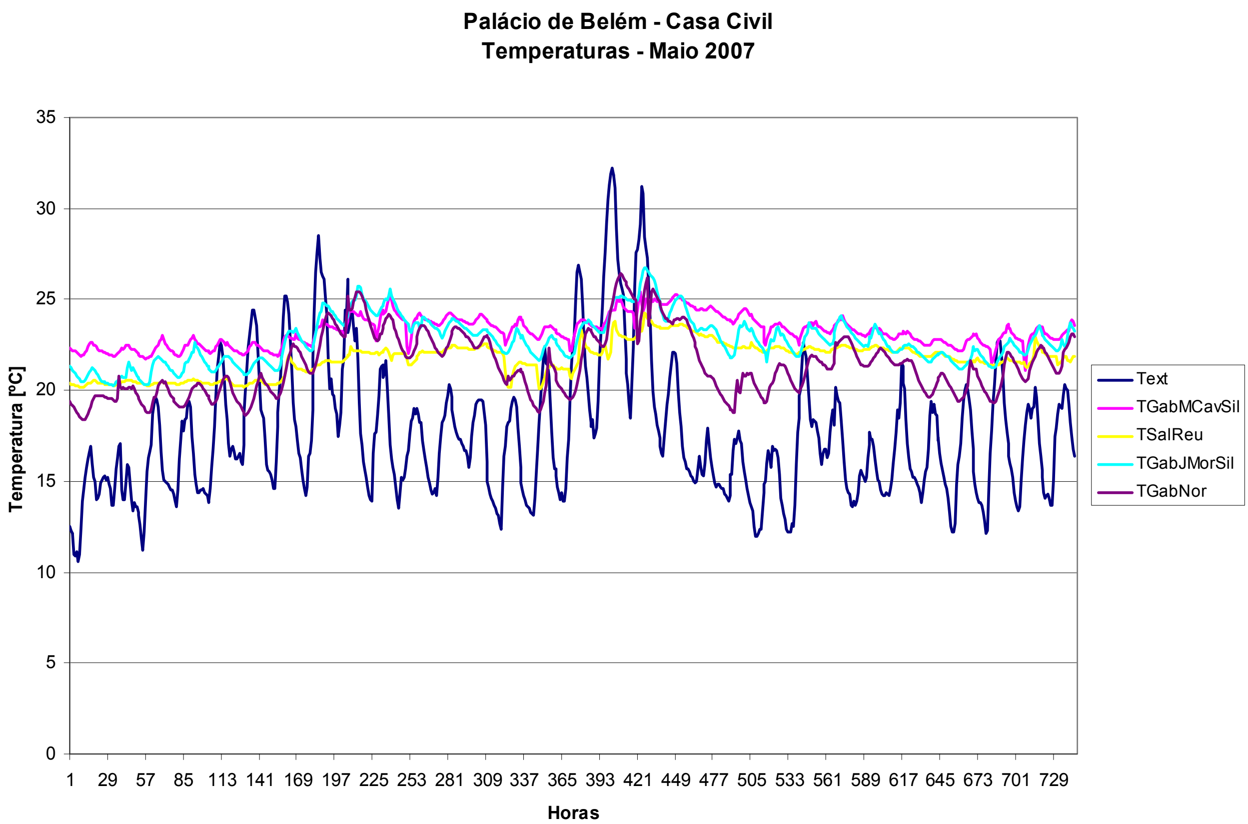


Figure 4 – Movement in hourly internal (Civil and Military Offices) and external temperatures

Following are the results obtained in RCCTE terms for the different parameters, as well as the energy classification within the scope of the Energy Certification of Buildings for the current situation.

Table 7– Energy Indices for the Civil and Military Offices

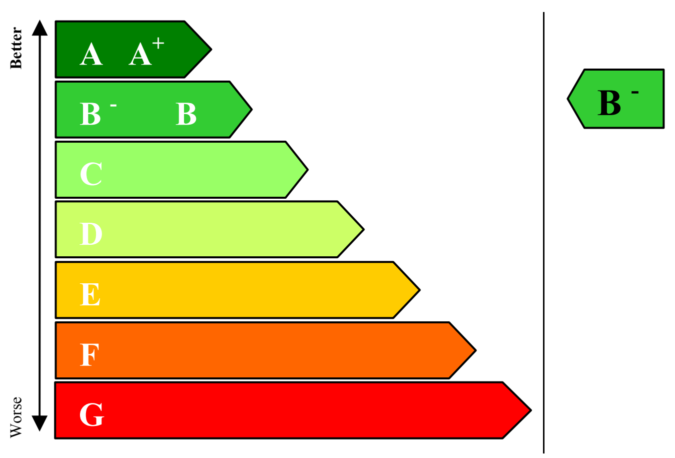
Current situation of the Civil and Military Offices
Heating Requirements: Nic ≤ Ni (Article 5)
61.84 (kWh/ m^2.year) ≤ 51.51 (kWh/ m^2.year)
Cooling Requirements: Nvc ≤ Nv (Article 6).
20.84 (kWh/ m^2.year) ≤ 32.00 (kWh/ m^2.year)
Hot Water Requirements: Nac ≤ Na (Article 7).
1.79 (kWh/ m^2.year) ≤ 2.08 (kWh/ m^2.year)
Total Requirements in Primary Energy: Ntc ≤ Nt (Article 8)
0.80 (kgep/m^2.year) ≤ 1.03 (kgep/m^2.year)

1. Label of energy performance

PERFORMANCE INDICES

Estimated annual global requirements of usable energy for air conditioning and hot waters	85	kWh/m^2.year
Estimated annual global requirements of primary energy for air conditioning and hot waters	0.8	kgep/m^2.year
Maximum regulated value for the annual global requirements of primary energy for air conditioning and hot waters	1.03	kgep/m^2.year
Annual greenhouse gas emissions related to primary energy for air conditioning and hot waters	1.63*	tonne of CO_2 equivalent per year

ENERGY CLASS



*Conversion factor used 0.0012 tonnes CO_2/kgep/m^2

Figure 5 – Example of a model of an energy certificate – Civil and Military Offices.

DOCUMENTATION AND INFORMATION CENTRE (DIC)

The appraisal of the energy performance of the Documentation and Information Centre (DIC) was based on the methodology adopted by the new Regulation of Air Conditioning Energy Systems in Buildings (RSECE, Decree-Law No. 79/2006, dated April 4.

The 2006 RSECE endeavours to interpret the global energy efficiency of a building through quantifying all the energy usages, in terms of primary energy as established in the Index of Energy Efficiency (IEE).

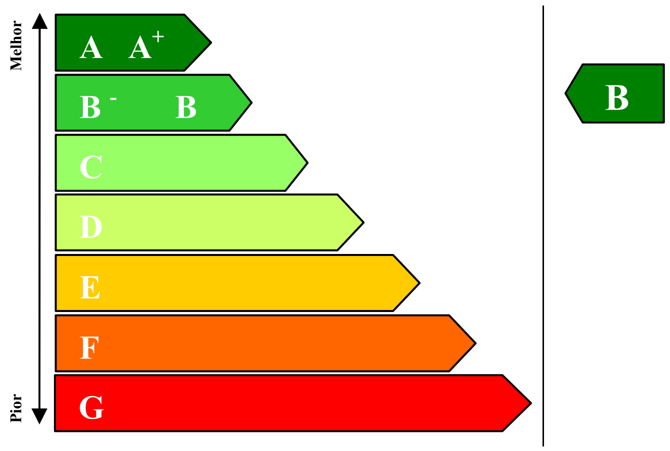
In addition to the fundamental thermal indices to check that it conforms to RSECE, the building will have to show the minimum requisites, demanded by the RCCTE regulation applied to the corresponding climatic region, in the terms of superficial and linear coefficients of thermal transmission of the surrounding elements, the inertia class of the building or its autonomous part, the solar factor of the window spans and the minimum obligatory rate of air renewal.

The nominal results ogtained for DIC comply with the regulatory requisite, since IEEnom<IEEref is sustained. These results are shown in the proposal of the Energy Certificate of the Building corresponding to Class B.

1. Label of energy performance

PERFORMANCE INDICES		
Estimated annual global requirements of usable energy for air conditioning and hot waters	71539.6	kWh/m^2.year
Estimated annual global requirements of primary energy for air conditioning and hot waters	22.4	kgep/m^2.year
Maximum regulated value for the annual global requirements of primary energy for air conditioning and hot waters	28.1	kgep/m^2.year
Annual greenhouse gas emissions related to primary energy for air conditioning and hot waters	86.0*	tonne of CO_2 equivalent per year

ENERGY CLASS



*Conversion factor used 0.0012 tonnes CO_2/kgep/m^2

Figure 6 – Example of a model of an energy certificate (DIC).

DIC was analysed in terms of energy performance in two offices located on the east side, since these were considered with apprehension by their users. The following table shows the average temperatures measured in those offices.

Relative maximum average temperatures are somewhat high for the two monitored offices (26.9ºC e 25.2ºC). In hourly terms the internal temperatures are in some cases quite high (28/29ºC), causing thermal discomfort.

Table 8 – Table of interior temperatures - May 2007

	Temperature [ºC]		
Location	Minimum averages	Maximum averages	Average
Office n-1	21.8	26.9	24.0
Office n-2	22.2	25.5	23.8
Office s-3	19.8	25.2	22.4
Office s-4	20.3	24.3	22.3
External	14.0	21.7	17.6

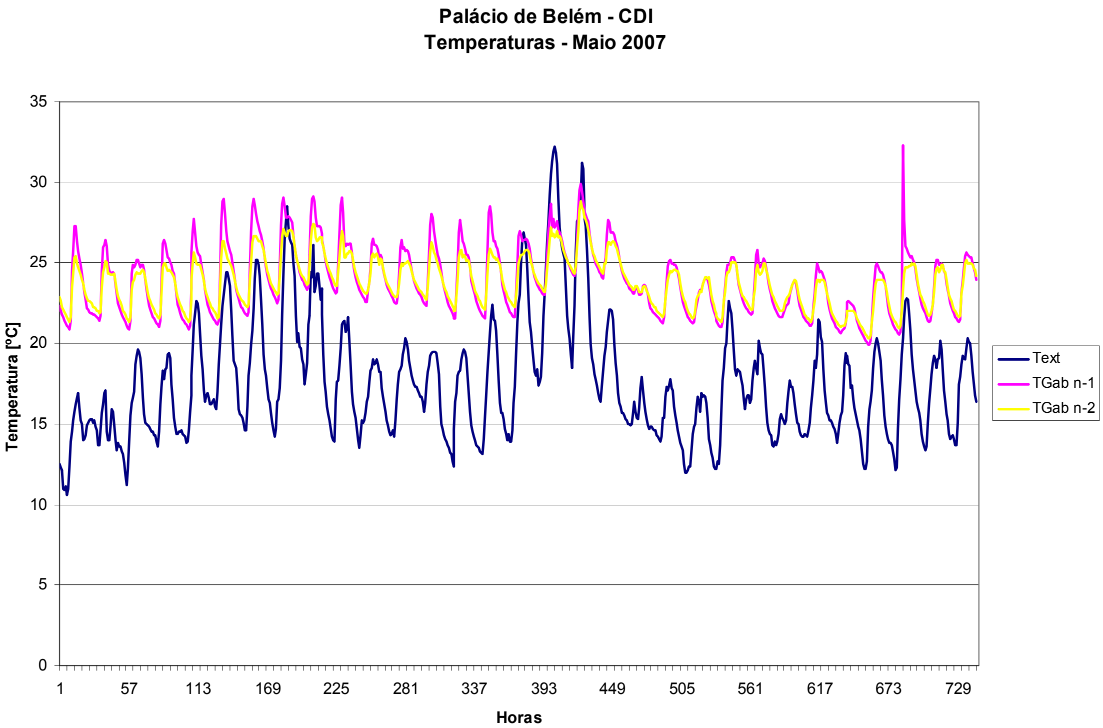


Figure 8 - Movement in hourly internal (offices of the Documentation and Information Centre) and external temperatures.

The remaining results are shown in the analysis of the thermal performance of each building contained in the INETI report.

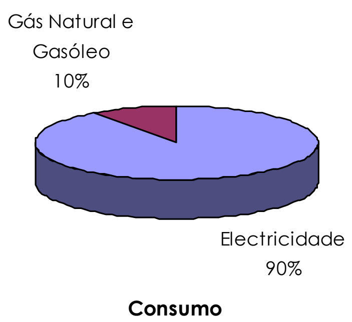
2.2 Characteristics of the usages of electrical energy

The electric energy installation in the complex of the Palace of Belém is currently being supplied in the Regulated System (EDP Distribution), in which the energy supply contract is in Medium Voltage with an Average Usage and Daily Cycle Tariff, 1,000 kVA installed Power and 465 kW Contracted Power.

In the reference period of this work (May 2006 to April 2007) the facility consumed a total of 1.48 GWh in electric power, corresponding to 424 toe which, in terms of CO_2 emissions to the atmosphere is equivalent to 643 tonnes of CO_2 eq/year.

Table 9 – Electric power consumed, cost and CO_2 emissions in the complex of the Palace of Belém

	Consumo	Custo	Emissões de CO_2
Electricidade	424 tep	127.131 €	643 ton CO_2 eq
TOTAL (inclui Gás Natural e Gasóleo)	**471 tep**	**156.711 €**	**771 ton CO_2 eq**



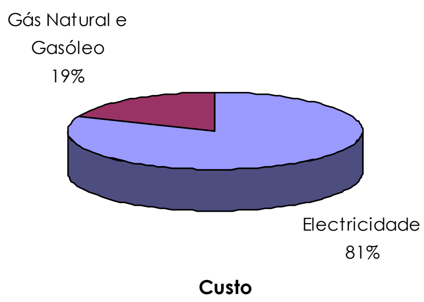


Figure 8 – Breakdown of energy usage by source and associated costs.

Electric energy consumed in the complex of the Palace of Belém is equivalent to 90% of the energy consumed and, in terms of cost, 64% of the total expenditure in energy.

The average price per kWh was 0.087 €/kWh corresponding to a total annual cost of 127,131 €.

In the monthly breakdown of electric energy consumed shown below, the lowest usage values happen in the months of March, April, May and October which are transitional months between the periods of high consumption in Summer and Winter. The variation between the maximum and the minimum usage of electric energy is approximately 37%.

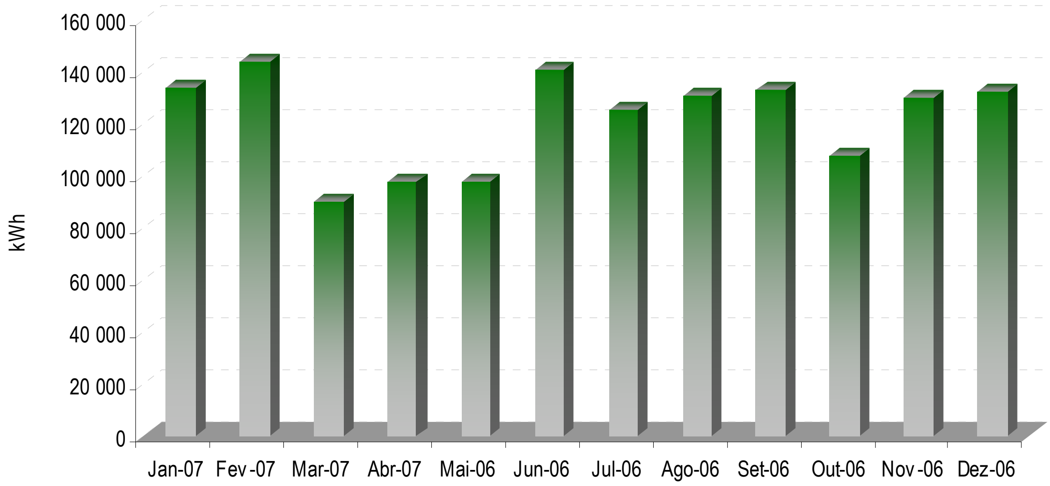


Figure 9 – Usage of electric energy in the reference period.

The analysis of the following figure shows that the highest cost in electrical energy took place in February amounting to 12,581 € and the lowest month was March with an amount of 8,609 €. The average monthly price was practically constant throughout 2006 and had a small increase (7%) in the 2007 monthly periods. The average price during the whole of the reference period was 0.087 € / kWh.

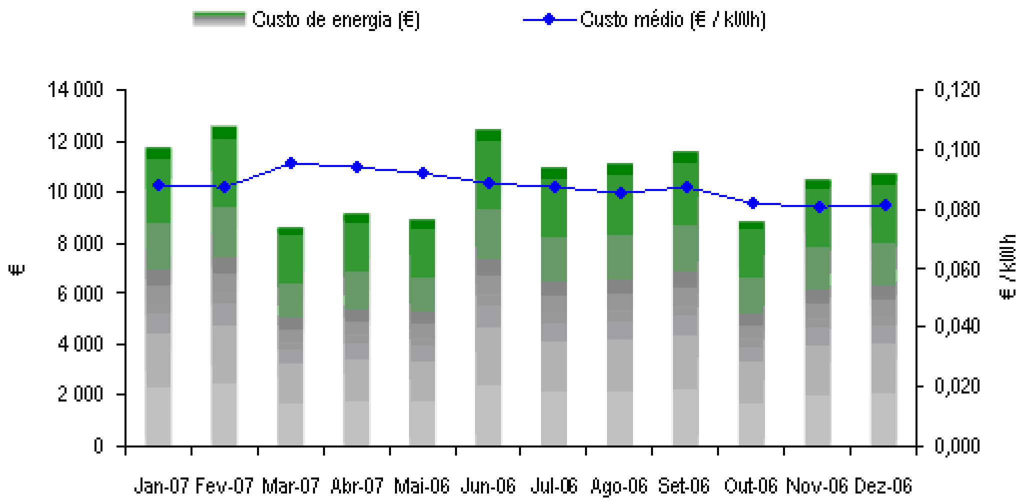


Figure 10 – Monthly variation of expenditure in electric power and monthly average price per kWh.

With respect to energy usage per sector/equipment, the largest electric energy consumers are connected to the switchboard supplying the Documentation and Information Centre (DIC), responsible for 23.9%. The Switchboards installed in the Palace Tunnels 1 and 2 are responsible respectively for 13.3% and 15.9% of energy usage. The switchboard in the building annexe to the Palace accounts for 15.6% of electric energy usage, whilst the Switchboard of the General Secretariat accounts for approximately 9.4%, that of the Museum for 4.3%, that of the Porter's Lodge for 3.2%

and the Switchboard of the Computer Centre 2.2%. Other sundry usages account for 12% of the total use of electric energy.

The following figure shows the breakdown of electric energy consumed in the various buildings:

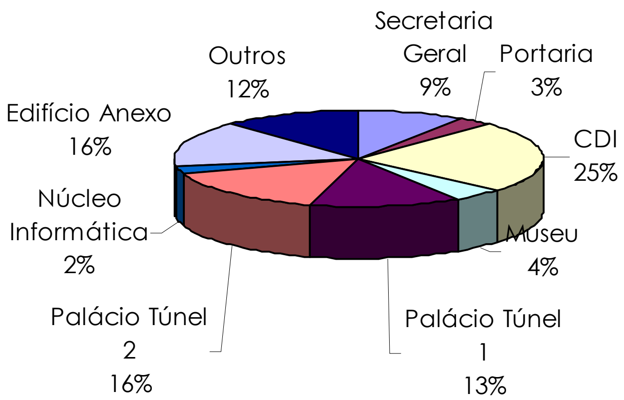


Figure 11 – Breakdown of electric energy consumed per building.

With respect to electric energy consumed per sector, it is estimated that 40% is related to lighting, 35% to air conditioning and the remaining 25% to power outlet circuits (including information equipment) as shown in the following figure:

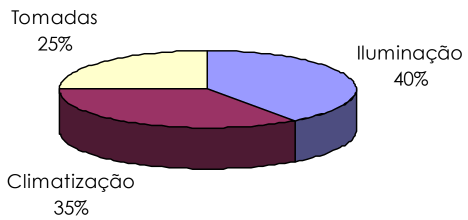


Figure 12 – Breakdown of electric energy consumed by sector.

2.3 Characteristics of usages of Natural Gas and Diesel Oil

In the case of liquid and gaseous fuels the objective of this audit was to assess the existing facilities, analyse the data relative to the usage of natural gas and diesel oil, as well as the analysis and the proposal of remedies for a more rational use of energy.

Within this scope the usages of thermal energy in the institution were determined globally and broken down by fuel type, during the reference period of one year, using as basic data the usages of natural gas recorded in the supply invoices (from April

2006 to April 2007) and of diesel oil recorded internally in the Presidency of the Republic (from March 2006 to March 2007).

The breakdown of fuel consumed in tonnes of oil equivalent (toe) is as follows:

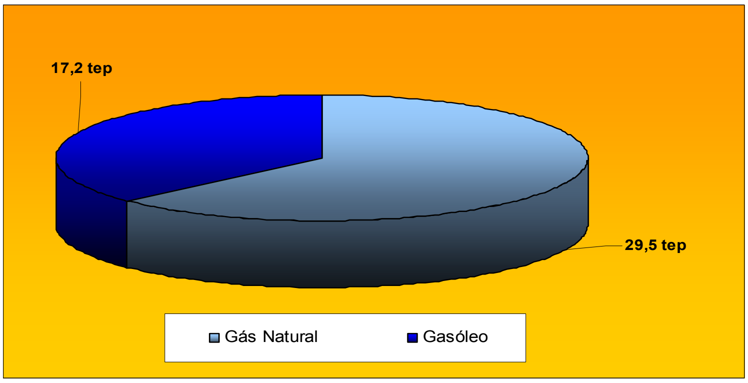


Figure 13 – Breakdown of Natural Gas and Diesel Oil consumed (2006-2007).

Thermal energy In the Palace of Belém (natural gas and diesel oil) is consumed in boilers and kitchen equipment. In addition there are two solar panels that support the production of sanitary hot waters.

Natural gas is supplied to the Palace of Belém through the "Lisboa Gás" Natural Gas Distribution Network, in a Low Pressure system, in three supply points located in: Calçada da Ajuda, Rua da Junqueira and Travessa dos Ferreiros.

Diesel oil supply is ensured through two fuel tanks installed in the Palace of Belém.

The simultaneous maximum power of all the equipments supplied by natural gas and diesel oil installed in the Palace of Belém amounts to 1,394.00 kW and is intended for the production of sanitary hot waters, air conditioning and kitchens.

Globally, the usages of natural gas and respective costs in the reference period were the following:

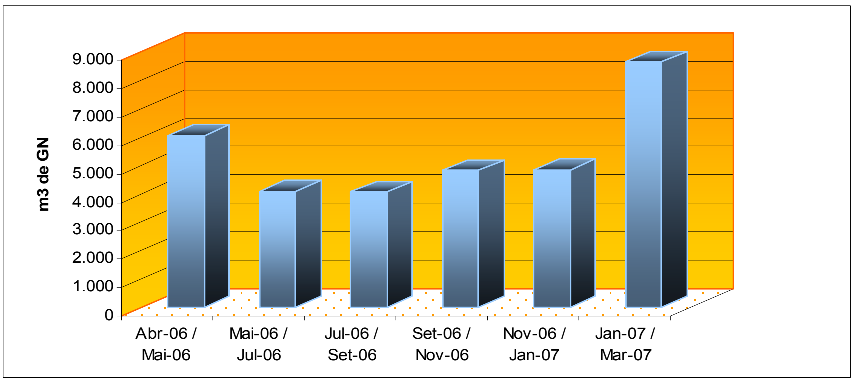


Figure 14 – Usage of Natural Gas 2006-2007.

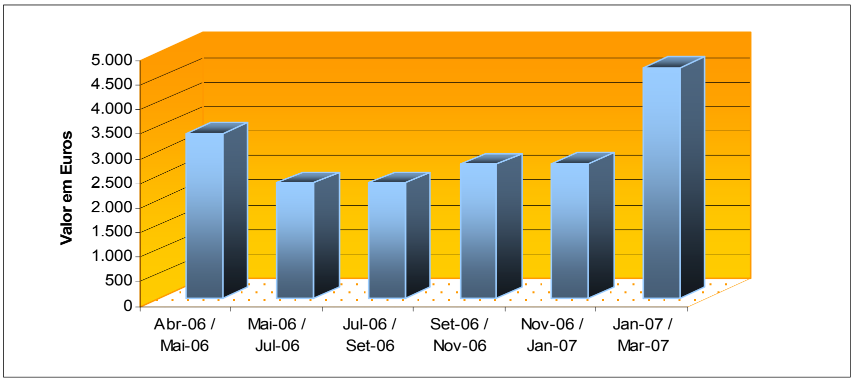


Figure 15 – Costs of Natural Gas 2006-2007.

The following table shows cumulative values of Usages, Costs and average price of natural gas in the reference period (Apr06 to Apr07):

Table 10 – Summary of Usages/Costs of Natural Gas

Period	**Volume [m^3]**	**Cost [€]**	**Average Price [€/m^3]**
Apr06 – Apr07	32,528	19,084	0.587

Values include VAT (5%)

Globally, the usages of diesel oil and respective costs in the reference period were the following:

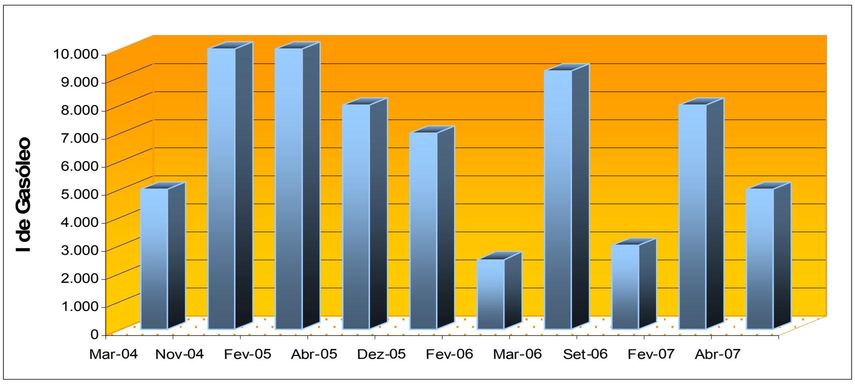


Figure 16 – Usage of Diesel Oil 2004-2007.

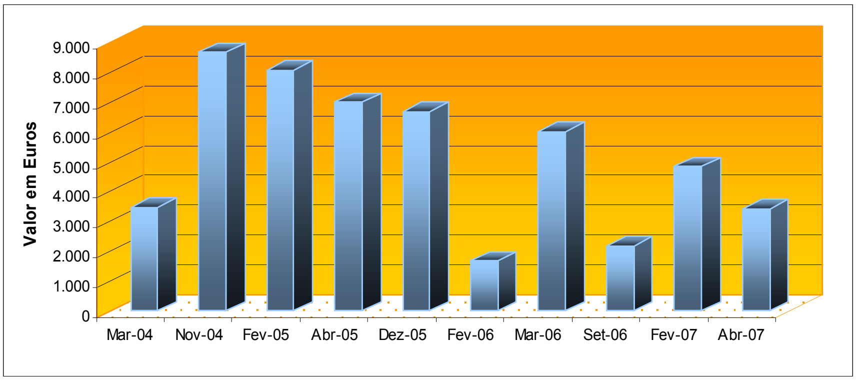


Figure 17 – Costs of Diesel Oil 2004-2007.

The following table shows cumulative values of Usages, Costs and average price of diesel oil in the reference period (Mar06 to Mar07):

Table 11 – Summary of Usages/Costs of Diesel Oil

Period	Volume [l]	Cost [€]	Average price [€/l]
Mar06 – Mar07	20,200	13,012	0.644

Values include VAT (12%)

Energy characteristics of the thermal equipment.

The following thermal equipment using natural gas and diesel oil, installed in the complex of the Palace of Belém were subject to analysis:

1 ROCA G40 boiler comprising two modules

- Nominal Power: 161 kW
- Fuel: Natural gas
- Location: Old garage
- Function: Air conditioning of the Documentation and Information Centre (DIC) and Hot Water production in the Old Garage
- Identified in this report as: "ROCA G40"
- Size: Height: 0.95 m; Width: 1.10 m; Depth: 0.90 m

2 A.O.Smith Thermal Accumulators

- Nominal Unit Power: 38 kW
- Fuel: Natural gas
- Location: DIC kitchen
- Function: Heating of sanitary waters (AQS) for the kitchen and DIC sanitary facilities
- Identified in this report as: "Smith1", "Smith2"
- Size of each accumulator: Height: 1.5m; Diameter: 0.7m

1 ROCA Kadet Tronic Boiler

- Nominal Power: 237 kW
- Fuel: Diesel Oil
- Location: Pátio dos Bichos
- Function: Central heating of the Palace Reception Rooms
- Identified in this report as: “Roca”
- Size: Height: 0,95 m; Width: 0,75 m; Depth: 1,40 m

1 IGNIS Boiler

- Nominal Power: 186 kW
- Fuel: Diesel Oil
- Location: Palace kitchen
- Function: Central Heating and Hot Waters for the Residence
- Identified in this report as: “IGNIS”
- Size: Height: 1,0 m; Width: 0,83 m; Depth: 1,53 m

1 Auxiliary Boiler

- Nominal Power: 29 kW
- Fuel: Diesel Oil
- Location: Palace kitchen
- Function: Hot Waters for the Residence
- Identified in this report as: “CaldPeq”
- Size: Height: 0,75 m; Width: 0,40 m; Depth: 0,65 m

The objective of the analysis was to establish the quality of combustion, the thermal losses and the thermal output of each of the tested items of equipment.

From the measurements obtained it was possible to carry out the energy balance of the various items of equipment and establish fuel consumption and thermal performance. The following Table and Graphs show the results obtained.

Measurements were carried out after an initial heating period of each item of equipment in order that its operation would be as near to normal as possible and continuous, without stoppages or start-ups.

An analysis of the results allowed establishing the low thermal performance of the items of equipment run on natural gas, primarily due to excessive air in the combustion process, considering the type of fuel used. This situation requires adequate action to be carried out by the maintenance staff.

Table 12 – Fuel consumption and thermal performance

Equipment	Fuel	Fuel consumption	Thermal performance
RocaG40 Boiler	Natural Gas	12.8 $m^3(n)/h$	83.7 %
Thermo accumulator Smith 1		3.7 $m^3(n)/h$	82.8 %
Thermo accumulator Smith 2		3.6 $m^3(n)/h$	78.7 %
Roca Boiler	Diesel Oil	12.9 kg/h	91.3 %
IGNIS Boiler		12.3 kg/h	86.0 %
Auxiliary Boiler		9.7 kg/h	71.1 %

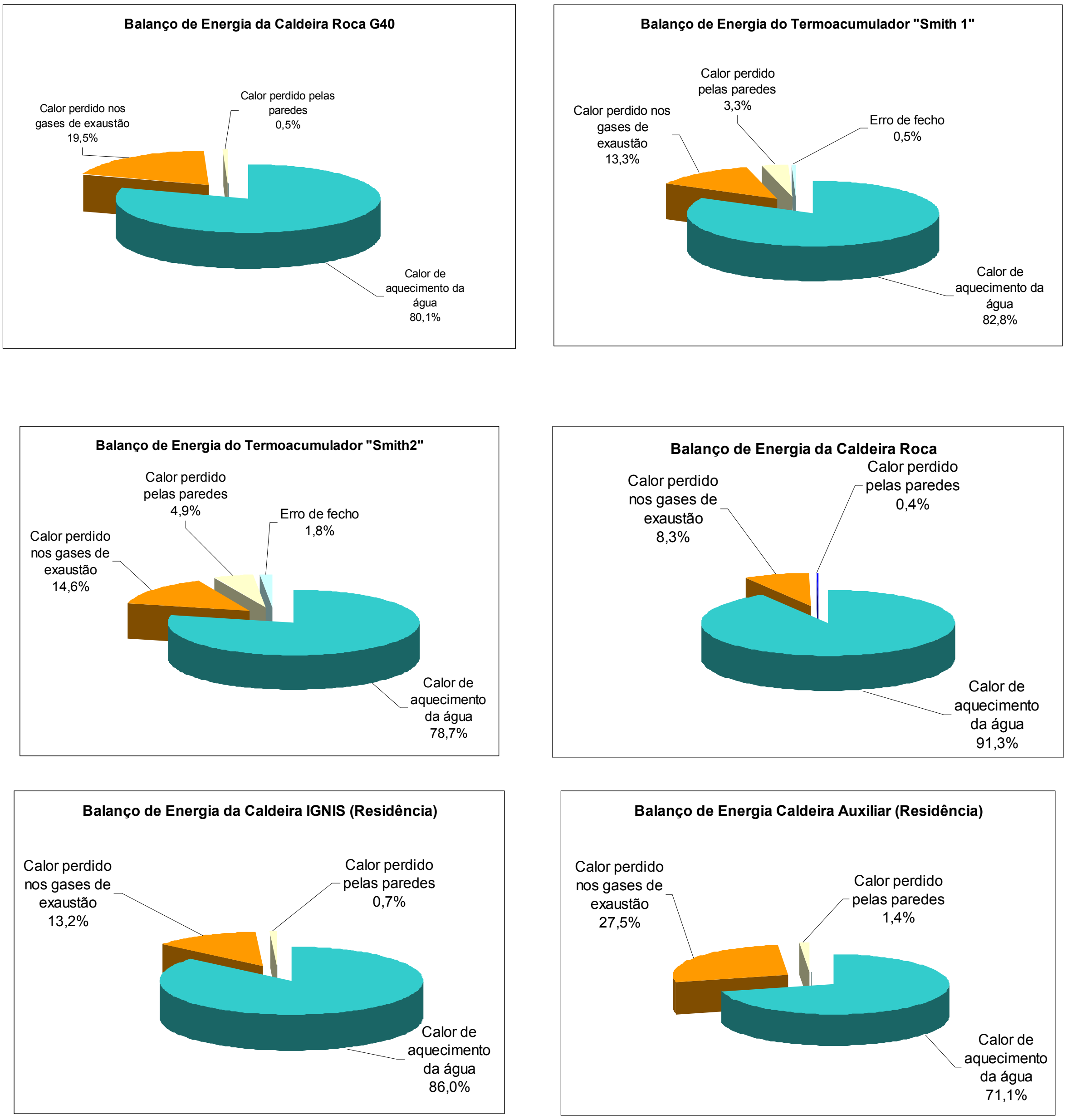


Figure 18 – Energy balance of the boilers and thermo accumulators

The gaseous effluents were monitored when the tests were run, to establish the gaseous pollutants (CO, NO_x, SO_2) and volatile organic compounds (VOC's) in the natural gas boilers and, also, samples collected to establish total particles in suspension (TPS) in the case of boilers run with diesel oil. The following table summarizes the results obtained for each of the effluents analysed.

Table 13 – Concentration of pollutants emitted

Parameter	Concentration $mg/m^3(n)$ dry gas, 8% O_2						
	RocaG40*	Smith1	Smith2	Ignis**	CaldPeq***	Roca	VLE
TPS	-	-	-	Not established.	Not established.	61	**300**
NO_X	135	192	194	130	143	103	**1500**
SO_2	< LD	<LD	<LD	<LD	<LD	<LQ	**2700**
CO	<LQ	<LQ	<LQ	27	261	18	**1000**
VOC	3	7	2	< LD	<LD	< LD	**50**

* during stationary running (continuous)
** average of the cycle
*** anomalous operation

All the established results are lower than the maximum emission values permitted (VLE). However, not all the values shown correspond to normal operating conditions, as described ahead.

Natural Gas Equipments

The values shown in Table 10 for the "RocaG40" boiler correspond to a period of normal operation (continuous). The values initially obtained on 11/06/2007 evinced a high content of volatile organic compounds (VOC), thus requiring that this monitoring test be repeated. VOC was not measured on 21/06/2007, however, O_2 contents on this day were much lower (down to 8.2% from 12.1%) and VOC diffuse emissions were measured on the front panel of the left module of the boiler reaching a maximum value of 340 ppm, that is, 140 $mg/m^3(n)$, without conversion to the reference O_2 , a value twice as large as the VLE, even without correcting for the oxygen content.

The thermo accumulators showed emissions considerably lower than the VLE.

Diesel Oil Equipments

Due to the discontinuous operation of the diesel oil "Ignis" boiler, it was not possible to establish the content of the total particles in suspension (TPS). Gases were established and registered continuously, Table 10, showing the average obtained during a start-up, running and closing down cycle, is represented graphically in the Figure below. It was however established that, even considering the average of an operational cycle, value are below VLE in all the pollutants measured.

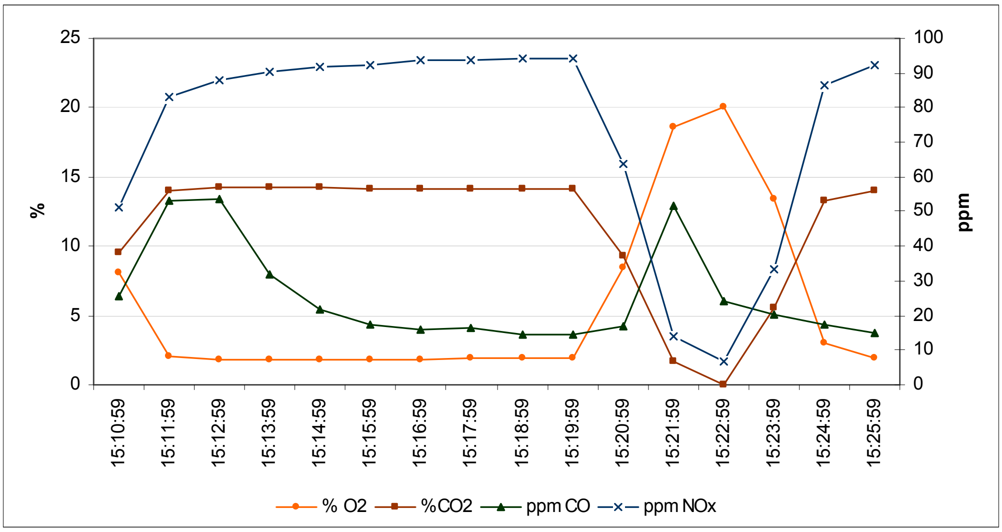


Figure 19 – Emissions of the"Ignis" Boiler during an operating cycle.

It was not possible to determine TPS in the “CaldPeq” boiler due to the smoke coming out of the front panel of this equipment and the smell of burning during the test, a situation confirmed by the increase in CO content. Values shown in the Table refer to the average of the test carried out, with the reservation that it does not correspond to normal operation.

Values obtained in the tests of the “Roca” boiler, located in Pátio dos Bichos and which is used for the central heating of the Palace reception rooms, were always below the VLE, it thus being apparent that the combustion system is tuned and operating in good conditions, as is anyway shown by the low TPS emissions and its high thermal performance.

2.4 Characteristics of the existing solar thermal system

A survey was carried out of the two solar thermal installations in the Palace of Belém in Lisbon to detect possible anomalies in the planning, installation and/or integration in the conventional system, which would justify the deficiencies in operation which have been noticed by the users.

There are two independent installations, differing in size and in finality: one to supply hot water to a private bath room and the other to supply hot water to the kitchen.

INSTALLATION A

Installation A is an installation in forced circulation that supplies hot water to a bathroom serving a private office.

The panels consist of a CPC solar collector with an area of approximately 2 m^2 which does not show signs of degradation but that, due to architectural constraints, is located practically horizontally, thus hindering its operation during winter.

The analysis of the lay-out of the installation does not call for any special comments, except in the case of the support system. In effect the positioning of the electric coil in the lower part of the reservoir together with the incorrect programming of the timer inhibits the priority of the Sun which should be the normal operation of the installation.

INSTALLATION B

Installation B ensures the supply of sanitary hot waters to the Palace kitchen, and consists of CPC collectors with an area of approximately 8 m^2.

The solar system as well as the support integration has been correctly installed. However, some of the components are not operating correctly and the positioning of some of the transit valves must be changed. In effect, due to the fact that the hot water circulation link connects the two tanks (solar and support), a transfer of energy is being induced between the support tank and the solar tank, eliminating the stratification of the water in the solar tank and thus inhibiting its contribution.

On the other hand the tank connected to the solar system should not have other sources of energy, and as such the incorporated electric coils should be suppressed.

3 MEASURES OF ENERGY OPTIMIZATION

The measures of energy optimization which are suggested following the energy audit carried out can be divided into two main groups: one based on time (very short term and medium term measures) the other on budget (reduced or nil cost measures or measures involving some budgetary impact).

As such, **Measures of sound energy management** are suggested which do not involve appreciable costs but have a relevant impact in the reduction of energy usage and a consequent lowering of CO_2 emissions, and **Measures of structural action,** which should be considered in the medium term, involving some investment, but with generally short payback periods and which lead to large reductions in energy usages and to the possibility of energy certification of buildings that could even be the object of classification in the higher echelons.

The following paragraphs highlight the proposed measures sub-divided in these two large groups.

3.1 Measures of sound energy management

Measures of sound energy management or of good practices for immediate application at reduced or nil costs.

a. Tariff change

The change of the current supply tariff to one for Lengthy Use and Weekly Cycle will result in a reduction in electric power costs of approximately **10,800 €/year** (8 %), since

the average price per kWh estimated for the current tariff is 0.0926 €/kWh, whilst that of the recommended tariff will be 0.0852 €/kWh.
This measure has nil costs.

b. Reduction of residual usage ("stand-by" usage)

It is recommended that any type of equipment, such as televisions, PC's and monitors, printers, scanners and photocopiers not in use should be totally disconnected and not remain in the "stand-by" mode.

This action is estimated to reduce annual electric power usage by approximately **4,941 kWh** (1.43 toe/year) which corresponds to a reduction in costs of **430 €/year** and avoid emissions totalling **2.17 ton CO_2 eq/year.**

c. Tuning of natural gas boilers (Roca G40, Smith 1 e Smith 2)

The natural gas boilers have very low energy performances for this type of fuel (between 78.7 e 82.8%), which should lead to an inspection of the boilers and tuning of the burners in order to detect the causes and correct the defects found. Considering that the output could reach 90% in similar equipment, it is estimated that the annual economy in natural gas will reach 2,660m^3(n), corresponding to 28,009 kWh, or 2,4 toe, equivalent to approximately 1,200 €/year. Annual reduction in CO_2 will be 5,666 kg.

Attention is called to the high rates of diffuse VOC emissions on the external surface of the "RocaG40" boiler, which requires urgent action for reasons of security.

This alteration does not involve capital costs, and should be charged to regular equipment maintenance.

d. Disconnect the thermo accumulators during week-ends (Smith 1 and Smith 2)

The thermo accumulators which supply hot water to the kitchen and to the DIC washrooms are currently in continuous operation. Fitting a timer which will permit their being disconnected during week-ends will result in an annual economy in gas of 793 m^3(n), corresponding to 8,350 kWh, or 0.72 toe /year, equivalent to approximately 357 €/year. Annual CO_2 reduction will be 1,690 kg.

This measure has nil costs.

e. Emissions

The operation of some of the items of equipment during tests may not represent their normal performance, since it was not carried out during a winter period, and as such possible differences could arise in the gaseous emissions. It is thus suggested that the thermal equipments should be tested under normal conditions, during next autumn/winter.

This measure has nil costs.

f. Insulation of the tubing in the boiler room of the Palace kitchen (Ignis and CaldPeq)

Insulating the hot water tubing located in the boiler room of the residency will permit an economy of 3,775 kWh, or 537 l/year of diesel oil, equivalent to 470 kgep/year, corresponding to an annual cost reduction of 346 €. The annual reduction in CO2 will be 1,417 kg.

This measure has an estimated cost of 140 €.

g. Change in the operating timetable of the Air Ventilation and Conditioning system (AVAC)

We suggest a change in the operating timetable of the AVAC system installed in the DIC, especially the chiller, currently operating 24 h/day during the whole year, as set out in the following table:

Table 14 – DIC – proposals for an operating timetable of the AVAC system

Equipment	Winter		Summer	
	Beginning	End	Beginning	End
Chiller	6:45 h	19:00 h	6:30 h	19:30 h

h. Change in the control system of smoke extraction in the Garage

It is suggested that the existing programmer for the control of the smoke extracting ventilators which operate through the detection of carbon monoxide, should be repaired or even replaced, in order that the equipment is not in operation 24 h/day, as is currently the case.

i. Change in the ventilating periods in the kitchens

It is suggested that the operation of the air extraction ventilators in the kitchen should be automatic in accordance with actual needs, during the normal canteen working hours, and not manually as is currently the case.

j. Operation of the hot water circulation pump in the DIC air conditioning system

The hot water circulation pumps for the air conditioning system installed in the DIC are in operation 365 days/year, including the periods when the boilers are closed down. It is suggested that such pumps operate only during the operating periods of the boilers which support the DIC air conditioning system.

k. Changes in the existing solar thermal systems

In installation A.

Considering the very low use of hot water produced by this system, the electric support coil should be permanently disconnected, and only used in extreme situations by providing its connection with a timing system. Operating periods should also be shortened.

This measure has nil costs.

In installation B.

The change suggested in this case is the alteration of the system by removing the hot water circulation link from the solar tank, purchase and install a 3-way motorized valve with a temperature sensor, to be fitted in the upper part of the solar tank, so as to allow the inflow of the water previously heated by the solar system, correct the positioning of the transit valves in order to guarantee the exclusivity of supply of network water from the support tank and permanently de-activate the electrical coils fitted in the solar tank.

This measure involves an estimated cost of 500 Euros, relative to the purchase and installation of the above referred 3-way motorized valve.

l. Swimming pool covering

The swimming pool for private use is an outdoor pool exclusively used during the hot and temperate seasons where the contribution of a solar system would be practically insignificant (very low requirements), apart from the difficulty in finding a nearby place with the required collecting area. It is thus suggested that a cover be installed over the water surface which would considerably reduce the night losses and would maintain the temperature of the water, heated by the Sun’s rays in daytime.

This measure has an estimated cost of 1000 Euros.

m. Usage Management System

The implementation of an electric energy metering system will allow detailed monitoring of the usages in the various sectors and/or items of equipment which are more representative in terms of energy.

It should be highlighted that all the information provided by the usage management system, based on which energy accounting may be set-up, can become an indispensable tool to detect eventual variations from the standard usage of the facility, as well as to keep track of the movement in usages after the implementation of the measures for Rational Use of Electric Energy.

This system when combined with the availability of real time on-line data and Energy Management, has the following advantages:

- Analysis of tariff options;
- Capacity to establish typical usage profiles;
- Alarms adapted to the Customer's requirements;
- Charge energy costs to different departments or sectors;
- Peak control: power taken and power in time;
- Export of data to other applications;
- Association of production *data* to the respective energy usages.

The following figure shows a view of the on-line site of the Usage Management System of EDP Corporate.

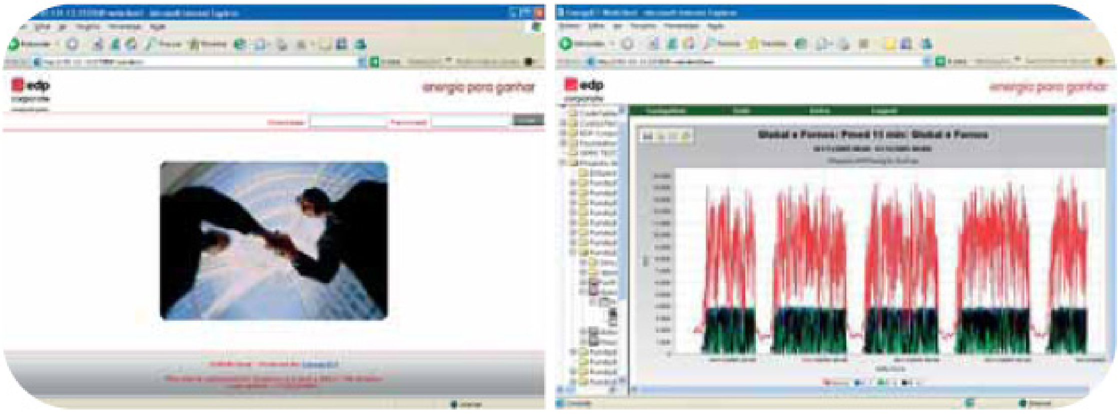


Figure 20 - On-line site of the Usage Management System of EDP Corporate.

n. Sensitizing Action on the Rational Use of Energy

The knowledge that it is more than ever important to develop firm actions to preserve the environment can be materialized through the change in postures and behaviours linked to the use of energy. Through simple measures of sound energy management it is possible, in part, to reach this target, with the consequent environmental benefits associated to the reduction in energy costs.

With the objective to sensitize the staff and service providers of the Palace of Belém to the importance, in their day-to-day tasks, of adopting behaviours leading to a correct use of energy, through simple measures which avoid waste, we propose carrying out demonstrative campaigns with the staff of the Official Residence of the President of the Republic.

The following table summarizes the **Measures of sound energy management** proposed, respective costs and impacts.

Table 14 – Proposed measures of sound energy management, costs and impacts

Measure	Benefit		
	Energy economy [kWh/year]	**Emissions avoided [tonCO₂ e/year**	**Value [€/year]**
Tariff change	n.a.	n.a.	10,800
Reduction of residual use ("stand-by" use)		2.17	430
Tuning of boilers	28,009	5.7	1,200
Disconnect thermo accumulators	8,350	1.7	357
Tubing insulation	3,775	1.4	346
Change in the operating timetable of the AVAC systems	22,740	10.0	1,978
Change in the control system of smoke extraction in the Garage	32,850	14.05	2,860
Change in the ventilation systems in the kitchens	2,080	1.0	180
Operation of the hot water circulation pump in the air conditioning system of the DIC	15,972	7.0	1,390
Change in the existing solar thermal systems	n.a	n.a	500
Swimming pool cover	n.a	n.a	1,000
Usage Management System[1]			
Sensitizing Action on Rational Use of Energy	n.a.	n.a.	12,000
Totals	113,776	43.5	33,041

3.2 Structural measures

These measures could involve a higher level of investment.

a. Measures involving the thermal quality of the buildings

Consideration was given to changes in each of the analysed buildings that would not imply architectural alterations. The changes are summarized as follows:

In the **Palace of Belém and in the Official Residence** three instances were considered in addition to the current situation:

1- Replacement of the existing window frames with Class 3 frames in line with the new energy regulation;
2- Maintain the current window frames adding double glazed windows (with Class 3 frames) and correcting some thermal bridging
3- Insulate the roof covering (20cm)

[1] Indirect impact measure of energy management; however, research reveals that the implementing of this type of energy control system could lead to an energy economy ranging from 5% and10% of the annual usage of the facilities.

No. 2 would be the more reasonable remedial solution, with the addition of new window frames to those already in existence, with tests previously carried out in some of the Palace's spans. No. 3 is the most efficient but surely the most difficult to materialize.

Results obtained in these three remedial solutions correspond to a reduction in the global needs of primary energy, from 1.2 kgep/m^2 /year to 1.14 (No. 1); 1.04 (No. 2) and 0.7 (No. 3), resulting in reductions of CO_2 tonnes eq. from 7.7 to 7.3 (No. 1); 6.7 (No. 2) and 4.5 (No. 3).

Two situations were also appraised in the **Civil and Military Offices**, in addition to the current situation:

1- Replacement of the existing window frames with Class 3 frames in line with the new energy regulation;
2- Maintain the current window frames adding double glazed windows (with Class 3 frames) and correcting some thermal bridging
3- Insulate the roof covering (20cm)

Occasional overheating in the Documentation and Information Centre (DIC) occurs during morning periods in the offices facing east, resulting in discomfort for the staff which requires correction. The best remedial solution would be an increase in the external shadowing of the spans facing that direction. This could be carried out by the erection of a light structure or by the more sophisticated installation of external movable screens.

The latter would be the best remedial solution, but has evident difficulties linked with the impact to the initial architectural design.

b. Increase in energy efficiency in the internal and external lighting systems

Considering the usage shown by the direct readings and the number of operating hours attributed to the lighting circuits, the following remedial solutions are proposed in order to increase the facility's energy efficiency.

As to **Internal Lighting**, we propose:

- Replacing the existing fittings of tubular fluorescent light bulbs equipped with ferro-magnetic ballasts, by fittings of tubular fluorescent energy saving light bulbs equipped with electronic ballasts with Class A Energy Efficiency.

- In those cases where it is not feasible to recover the fittings with tubular fluorescent bulbs and conventional ballasts, we propose their total replacement by high yield energy efficient luminaires equipped with high frequency electronic ballasts and T5 tubular fluorescent bulbs.

- Replacing the normal incandescent light bulbs, installed in lamp standards and in ceiling fittings, by compact fluorescent bulbs equipped with electronic ballasts.

- Replacing the ferro-magnetic ballasts in the luminaires equipped with compact fluorescent bulbs by electronic ballasts and Class A energy efficient bulbs.

- Replacing ferro-magnetic transformers and 50W halogen incandescent bulbs, by electronic transformers and 35W halogen incandescent bulbs with IRC technology.

- Installing detection of movement/presence cells in order to control lighting in the required location in line with presence.

Example of energy saving bulb for replacement in lamp standards

- Implementing programmable timing switches to control lighting in the following areas (e.g.): Garage Store, archives, pantry and Library.

- Redefining some of the electric circuits which control lighting in the following areas (e.g.): Library, archive and Chancellery archive.

As to **External Lighting**, we propose:

- To control the timing of the external lighting circuits, replacing the existing system (time switch, crepuscular cell and manual control), it is proposed that two astronomical clocks should be installed, one for external lighting controlled in the DIC switchboard and the other for external lighting controlled in the Porter's Lodge. This type of equipment provides a rigorous control of the operating periods of the external lighting circuits, in accordance with the latitude/longitude of the location where it is installed, adapting on a daily basis the timing of the operation of external lighting, in line with sunrise and sundown.

- Replacing the halogen bulbs by metallic iodine bulbs (more energy efficient).

c. Conversion of diesel oil usage to natural gas

Since the energy obtained from natural gas is more economic, its use will bring an annual reduction in costs and avoid additional costs relative to the use of other fuels.

The Energy/Economic Balance carried out for the fuel usage in the Palace of Belém showed that, economically, the conversion of diesel oil fuelled equipment to natural gas would bring a reduction in global costs for the institution amounting to 5,376 €, which corresponds to a 20% reduction in operating costs with these fuels.

The use of natural gas as a fuel for the production of thermal energy also has other advantages, such as:

- The adoption of natural gas as a fuel contributes towards achieving the environmental objectives demanded by the European directives since its CO_2 emissions are comparatively lower than those of other fossil fuels;

- The absence of sulphur, ash and other harmful particles in the composition of natural gas guarantees, on the one hand, a minimum level of pollution and, on the other, a simpler conservation of the equipment, less wear and tear and lower ordinary and extraordinary maintenance costs;

- With natural gas, the yield under real conditions will show 3 to 6% higher values than with other fuels, particularly in boilers, due mainly to the deposit of residual products of the combustion of diesel oil on the surface of the heat exchange;

- Boilers equipped with diesel oil burners can be altered, solely requiring the replacement of the burners with others adequate to burn natural gas;

- The storage area can be used for other purposes;

- Dangers and inconveniences derived from delivery and storage will no longer exist;

- Costs of maintaining diesel oil stocks will disappear.

As such, considering the Energy/Economic Balance carried out, the above referred advantages of the use of natural gas and its availability in the Palace of Belém, the re-structuring of the existing internal gas distribution network was analysed in order to allow the conversion of the current use of diesel oil to natural gas.

In order to ready the installation to the requisites of the new fuel, it will be necessary to build new sections of underground and aerial tubing to interconnect the existing networks with the new user sites and to replace the currently existing diesel oil burners with natural gas burners, in accordance with the Project for a Receiving Facility enclosed with this report, with the investment to carry out this work estimated at 39,978.00 € with a payback period of 7.5 years.

The conversion of the total use of diesel oil to natural gas corresponds to a reduction in CO_2 emissions of approximately 15 tonnes/year.

Given that the institution already has natural gas installed and that the conversion of the current use of diesel oil to natural gas is technically feasible, this is a good opportunity to improve the system's efficiency, increasing its output, diminishing contaminating emissions and lowering operating costs.

As a complement of the new natural gas system, the optimization and/or expansion of the solar panels would be desirable, with the aim to improve the efficiency of the hot water production system.

Considering the integrated natural gas/solar thermal system of hot water production to be implemented in the DIC canteen, the annual usage of natural gas will add up to 45,678 m3. In accordance with the new usage of natural gas the energy/economic balance was recalculated. From the economic point of view this new natural gas/solar thermal integrated system will result in a global 20% cost reduction for the institution, relative to the current system (6,550.45 €/year).

Considering the cost estimates to implement the solar system, of 16,000 € (INETI data) and the 39,978 € investment related to the conversion of the current diesel oil usages

to natural gas, the payback period for the investment in natural gas/solar thermal system has been calculated at 8.6 years.
The adoption of the natural gas/solar thermal integrated system will represent a reduction of approximately 25 tonnes/year CO_2 emissions, relative to the current situation.

d. **Installation of new systems of Renewable (Solar thermal and Solar Photovoltaic).**

From the analysis of the usage of hot waters in the Palace of Belém complex, it can be concluded that a relevant contribution could be provided for the canteen hot water system. Information collected on site resulted in an estimated usage of 2,500 litres per weekly working day. As such a solar system with an area of approximately 50 m^2 would result in an annual saving of approximately 75% of the required energy and would use a very small area of the canteen roof (which has an area of 100 m x7 m).

This installation has an approximate cost of 16,000 € and would allow saving 4,760 m^3 of natural gas per year, which at the current price of this gas would lead to an 8 year payback period (when the useful life of the equipment averages 20 years). Equivalent CO_2 avoided emissions will be approximately 12 tonnes per year.

The installation of a Solar Photovoltaic system for the production of electric energy with 5 kWp power on the roof of the DIC canteen (approximately 50 m^2, with a 30º module inclination), connected to the electric network would allow an annual production of 7,538 kWh. The cost of the system would be approximately 25,000 € and if the electric energy produced should be sold to the network in line with tariff foreseen in current legislation (DL 225/2007 – 0.542 €/kWh for micro-generation photovoltaic power stations with up to 5 kW power) the payback would be 4,086 €/year, equivalent to a simple payback period of 6.1 years. The avoided CO_2 equivalent emissions would be approximately 5.3 tonnes per year.

The following table shows the **Measures of structural action** proposed, respective costs and impacts.

Table 15 – Measures of structural action

Measure	Cost €	Benefit		
		Energy economy [kWh/year]	Emissions avoided [tonCO2 e/year]	Value [€/year]
Measures involving thermal quality of buildings	n.a*	*82,000***	2	n.a
Increase in energy efficiency of the internal and external lighting systems	92,000	230,000	101	21,200
Conversion of diesel oil usage to natural gas	39,978	n.a	15	5,76
Installation of new Renewable energy systems (Solar thermal)	16,000	35,091	12.0	5,759***
Installation of new Renewable energy systems (Solar photovoltaic)	25,000	7,538	5.3	4,086

*refurbishment requires detailed study of specialist action
**Savings obtained in the Palace and Residence with remedy 2 and Civil and Military Houses (remedy 3) in line with RCCTE methodology (Energy Requirements).
*** Average value calculated at the 10th year

4 ANALYSIS TO THE SAFETY CONDITIONS OF THE GAS AND ELECTRIC FACILITIES

4.1 Gas facilities

The following recommendations should be taken into consideration as to the safety of the gas facilities:

- The users of the facilities should be acquainted with the safety conditions with respect to the operation of the various burner equipments;
- Preventive maintenance of the facility, including inspection of the visible parts of the equipment and checking that no leaks exist over the whole network;
- Promote the Periodical Inspections to the gas facilities, in accordance with the provisions of Ordinance No. 362/2000 dated June 20, which must be carried out as established in article 13 of Decree-Law No. 521/99, dated December 19, every two years, for the gas facilities pertaining to the tourist and restaurant industry, schools, hospitals and other health services, barracks and any other public or private establishments with a capacity exceeding 250 persons.
- Corrective maintenance, at any time an anomaly is detected, either as a consequence of the preventive Maintenance report or as a consequence of a Periodical Inspection.

In compliance with the legislation in force, an inspection to the visible parts of the Natural Gas facilities in the Palace of Belém was carried out, on April 20, 2007, by an Inspection Body – the Institute for Gas Technology. The report issued by this Body called attention to several instances, which must be corrected:

Travessa dos Ferreiros delivery point

- Replace the exhaust tubes of the bathhouse boilers, which are located below the air intakes of the adjacent buildings.

Rua da Junqueira delivery point

- The gas facilities of the Staff Quarters, downstream from the metering group, must not be fastened to wooden walls; the switching valves on the outside of the building are not accessible.

- The Laundry gas facility crosses the sanitary installations, thus not complying with the provisions of item b) of §3 of art. 16 of Ordinance 361/98 dated June 26.

- The Museum boilers are on the inside of a closed cupboard.

In order to assess the whole facility, it is necessary to carry out sealing tests and to check the conditions of ventilation and exhaust of the combustion products. The Palace of Belém must thus request that a Periodical Inspection to its gas facilities should be carried out.

4.2 Electric energy facilities

The technical inspection of the electric energy installation aimed to assess its conformity with the regulatory minimum safety requisites in force and the sound technical practice.

The starting point of this investigation was solely the situation in which it was encountered when the visual and instrumental checks were carried out. For this reason it was not possible to identify absolute conclusive causes with respect to situations existing prior to or after the installing process, due to eventual changes in the installation itself, changes in the air or ground humidity and condensation in the cable ducts.

In this context a visual and instrumental check, based on the analysis of the electric circuits was carried out with respect to electric safety, with the following results:

- Although the installation had been carried out in accordance with the regulations contained in the annexes to Decree-Law No. 740/74, dated December 26 which meanwhile was revoked in the case of new electric installations or those re-installed at a date later than November 11, 2006, the electric installation did not respect, as to various requisites, the regulations in force at the time it took place.

- Several non-compliances with the applicable electric regulations are evident, especially the lack of protection from direct contacts, indirect contacts, lack of continuity of the grounding cables, lack of differential protection (medium and high) and incorrect protection of the circuits which compromise personal and/or user safety;

- Several defects were detected as to the insulation of some of the circuits which compromise personal and/or user safety and, directly, the operational status of the electrical installation, which could give rise to eventual short circuits or overloads which could seriously prejudice the referred facility and be the cause of possible damages (e.g. fire risk);

- In accordance with the provisions of Decree-Law No. 517/80, dated October 31, with the changes introduced by Decree-Law No. 101/2007, an up to date project should exist with respect to the current electrical installation and available for the purposes of maintenance and/or repair;

- It is recommended that protected power points should be installed in locations accessible to children and the general public;

- Screens should urgently be installed in wall brackets and lamp standards with bulb holders which allow direct contact in order to avoid electrocution risks;

- The use of protection against indirect high sensitivity contacts is recommended for the circuits in locations BB2, BB3 e BC3 in line with the external influences identified in sections 322.2 and 322.3 of R.T.I.E.B.T. (Technical Rulings for Low Voltage Electrical Installations);

- In all locations where two distinct power supplies exist there should be an indelible warning device next to the general circuit breaking appliances in each switchboard advising the existence of other connected switchboards;

With respect to thermo graphical records no anomalous temperatures were registered, considering the times and dates of the readings. It should be pointed out that some of the temperatures recorded were near the limiting values. Monitoring is recommended when the ambient temperature is higher.