Reducing carbon emissions in the Greek hotel sector: Case study Sami Beach Hotel, Kefalonia

by

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To my beloved father John Dorizas

« ’Εν οίδα ότι ουδέν οίδα...»
Socrates

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Abstract

The tourism industry has presented a significant growth over the last decades. Tourism in Greece is a substantial sector of the Greek economy accounting 15% of the country's Gross Domestic Product (GDP). Hotels are one of the most energy intensive sub-sectors of the tourism industry, which can surely affect global greenhouse gas emissions.

This project aims at presenting the effect of using energy efficient techniques, as well as Renewable Energy Sources (RES) such as photovoltaics, in the overall energy consumption of Greek hotels. This project is based on a case study three star category, seasonally operating hotel in the island of Kefalonia, in the Ionian cluster, in western Greece. Data concerning the building's construction, and the hotel's electricity, lighting, cooling and hot water production were collected. The annual total energy consumption of the hotel is 95 kWh/ m^2. After designing a model of the hotel in a thermal simulation's software, which approached the actual case, a series of simulations were carried out in order to assess the effectiveness of different energy conservation techniques in reducing cooling loads. While this process, special care was taken in order to maintain internal temperatures within required levels, since it constitutes an important consideration for visitor's satisfaction. Based on the results of the simulations it was found that the overall energy consumption can be reduced by 10%. Further significant reductions in the energy consumption, may be achieved by the installation of PVs. The combination of energy efficient techniques together with a PV installation on the hotel's roof caused a reduction by 60% in the electricity consumption from the existing case scenario. The percentage of CO_2 reductions from the current case reached 57%, corresponding to 50 tonnes, while the total cost per CO_2 removed for the life-time of the upgrading together with the PV installation is 300€.Furthermore, this project presents a rough cost analysis of the energy efficient techniques followed by an evaluation according to the potential savings each of them can achieve.

It is concluded that in the long term, the benefits arising from the adoption of energy conservation techniques concern energy, financial savings and reductions in the environmental impact by the decrease of carbon dioxide (CO_2) emissions. Therefore, it is essential to increase the awareness and support hoteliers and local authorities to promote the application of energy efficient technologies and RES.

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The choice of symbol for the thousands decimal separator that will be used throughout this project will be the period (.), for instance: 1.234,5=1,234.5.

CHAPTER 1

1 INTRODUCTION

Tourism constitutes one of the world's largest industries which has shown a remarkable increase the last decade, and which according to the long term forecast of the World Tourism organization (WTO), tourism is expected to double by 2020 (WTO 2001) (Figure 1). This increasing trend in tourism mobility results in ongoing building construction mainly for accommodation purposes as well as in significant growth in the circulatory system in developing areas such as islands. This rising trend affects significantly the global economy and results in increasing CO_2 emissions which in turn enhances greenhouse effect and can lead to climate change.

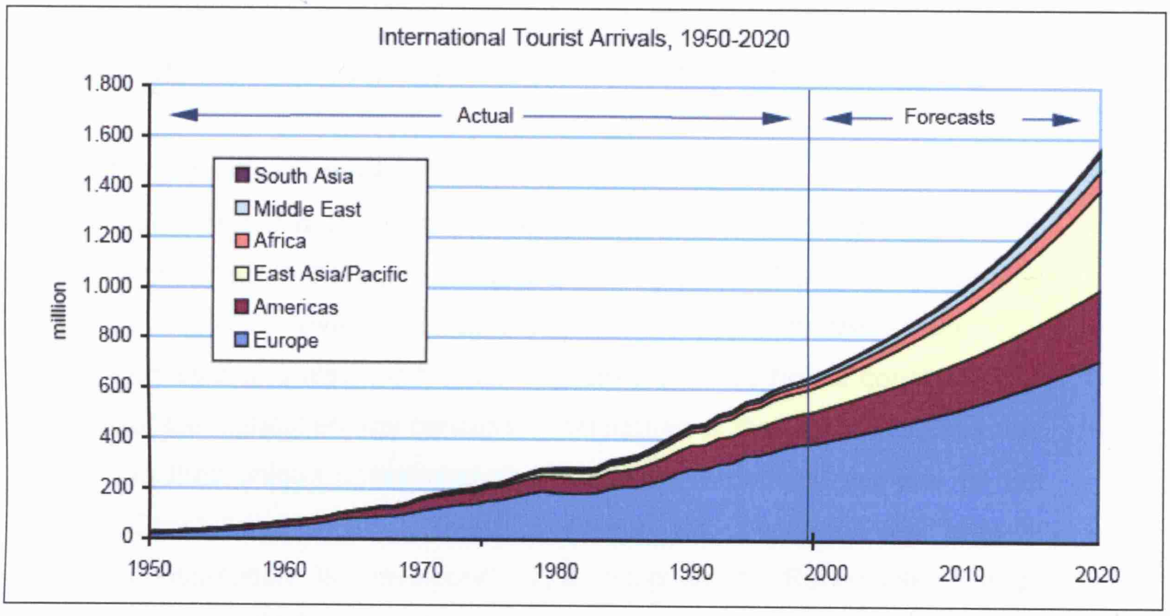


Figure 1: International Tourist Arrivals, 1950-2020 (Source: WTO 2001, p. 46)

This project focuses in the hotel sector and it aims to determine the energy demands of hotel units as well as to suggest energy efficient measures which will improve the overall energy performance of the buildings, based on data collected from a case study hotel in Kefalonia in Greece.

Furthermore, the environmental and economic benefits of reducing energy consumption will be discussed. Some of the principal questions that this paper will try to adhere to are the following:

- Which are the main categories affecting the energy consumption of hotels?
- Which of the energy conservation techniques leads to the greatest energy savings?
- How feasible is in practice to implement the energy saving techniques without compromising customers thermal comfort?
- Which are the potential savings in CO_2 emissions after the upgrading?
- What are the benefits and drawbacks of the application of renewable energy techniques such as photovoltaics?

The structure and methodology of the present dissertation is the following:

PART 1: Literature review

- **Chapters 2 & 3:** Contain a literature review in climate change and its confrontation through the regulatory context in a Global, European and a National level. The contribution of tourism to the global CO_2 emissions is also examined. Furthermore, since hotels constitute one of the highest energy consuming categories of the tourism industry due to their unique operational characteristics, a detailed analysis on the Greek hotel sector followed by researches concerning their energy consumption is developed. The adoption of Renewable Energy Sources (RES) in Greek hotels is also mentioned.

PART 2a: Methodology- Monitoring-Data gathering

- **Chapters 4, 5 & 6**: In order to define which are the most appropriate energy saving techniques for the hotel sector the collection of specific data including the identification of the thermal comfort conditions and the energy characteristics of the certain building are necessary.

This study will be based on the findings from a case study hotel "Sami Beach" located in Kefalonia, Greece. Information concerning the prevailing climatic conditions and the hotel's building construction, the cooling, hot water production systems as well as the electricity and fuel consumption are collected. A clear energy profile of the building including the distribution of energy in the different sectors is created. The annual CO_2 emissions for the existing case are estimated and the comparison of the energy consumption of the case study to findings from other researches in Hellenic hotels is presented.

Part 2b: **Methodology- Modelling**

- **Chapters 7 & 8**: Taking into account the current energy profile of the case study building and the potential areas of energy conservation, several energy efficient techniques will be applied and evaluated using the Thermal Analysis Software. The effect of each of the energy saving measures on reducing cooling loads is assessed through a series of simulations. Further energy savings techniques are proposed in a theoretical approach in order to reduce the building's overall energy consumption. Lastly, a rough cost analysis for the most energy efficient options is presented.
- **Chapter 9:** Furthermore, the techno-economic feasibility of a grid connected PV installation on the roof of the case study is examined through a Renewable Energy Technologies Software, RETScreen.

Part 3: Discussion & Conclusions

- **Chapters 10 & 11:** A summative approach of the total energy saving options adjusted to the corresponding approximate costs and reductions in the CO_2 emissions is presented followed by a critical analysis of the results. In the conclusions chapter a summary of the project's findings and a list of possible sustainability opportunities are proposed.

CHAPTER 2

2 CLIMATE CHANGE REGULATORY CONTEXT & TOURISM

One of the greatest environmental, economic and social threats that our planet is facing is climate change. The rapid increase of greenhouse gases due to the continuously growth in burning of fossil fuels from human's activities, contributes to unpredictable changes in the global climate. The most severe effects of climate change are extreme weather phenomena, significant increases in temperatures, changes in rainfalls, sea level rise, floods, droughts and damages in ecosystems.

2.1 Global level and regulations

In 1979 the World Meteorological Organization (WMO) organized the first "World Climate Conference" in which they expressed that "continued expansion of man's activities on earth may cause significant extended regional and global changes of climate" (WMO 2004). In 1988 the WMO and the United Nations Environmental Program (UNEP) established the Intergovernmental Panel on Climate Change (IPCC), a scientific body which will provide information and will evaluate the risk of human activity to climate change (UNEP 2007). The IPCC aims to assess scientific, technical and socio-economic literature concerning human's contribution to climate change (IPCC 2008).

The most evident effect of climate change is global warming. The increased concentrations of greenhouse gases prevent the amount of excessive heat to be radiated back to the space. Therefore, it results in enclosing that heat into the atmosphere and it increases the Earth's surface temperatures. The average global temperature has increased by 0,74 ^{0}C over the last hundred years and according to predictions from the IPCC, is expected to rise from 1,1 to 6,4 ^{0}C by the end of the 21st century (Figure 2) (IPCC 2007 p.13).

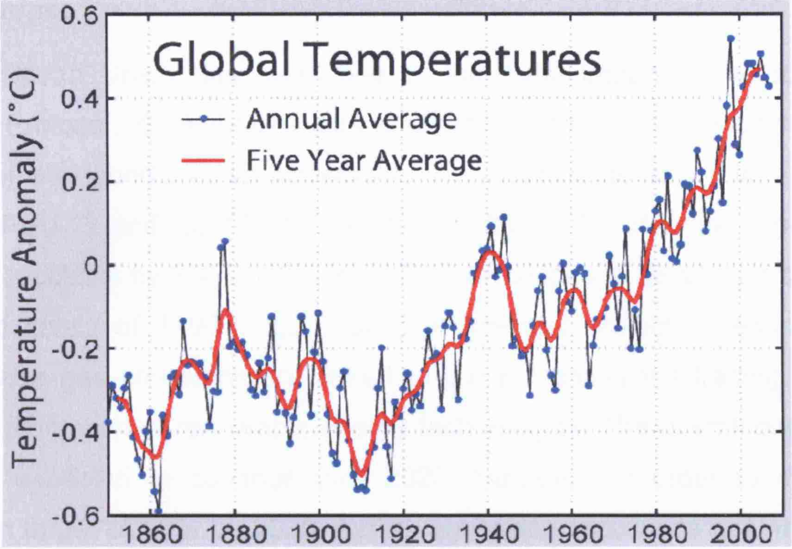


Figure 2: Global mean surface temperature anomaly relative to 1961-1990 (Source: Wikipedia 2008a)

The most important greenhouse gas is CO_2 whose concentrations have dramatically increased from 280 ppm to 380 ppm since the industrial revolution, due to human activities and mainly due to burning of fossil fuels. The concentrations of atmospheric (CO_2) are approximately 30 billion tonnes per year (Wikipedia 2008a).

In order to combat climate change and its catastrophic consequences, in 1997, industrialized countries referred as Annex I countries, ratified the Kyoto's protocol. Under the UN Framework Convection on Climate change (UNFCCC), the protocol aims at decreasing greenhouse gas concentrations in the atmosphere and therefore mitigating anthropogenic interference in climate change (EEA 2008, p. 31). Each of the ratified countries commits to reduce greenhouse gas emissions to certain specified levels and to submit the annual inventory of the reductions to the United Nations.

2.2 Europe

The European Union has been one of the most important supporters of Kyoto's Protocol. Greenhouse gas emissions from EU-27 account about 10,5% of the world's GHG emissions. The achievements by the member states of EU-12 and EU-15 of Kyoto targets by 2008-2012, are expected to lead to reductions by 2,4% of the total GHG emissions of developed countries from the levels of 1990 (Figure 3). The greatest projected reductions of greenhouse gas emissions are linked to the EU emissions trading scheme and the promotion of renewable energy technologies. The overall decreasing trend is expected to continue until 2020. However, in order to meet the reduction target of 20% by 2020, further emissions reductions are necessary (EEA 2008, p. 7). A summary of the planned measures and progress towards the respective Kyoto targets of each country is presented in table 1.

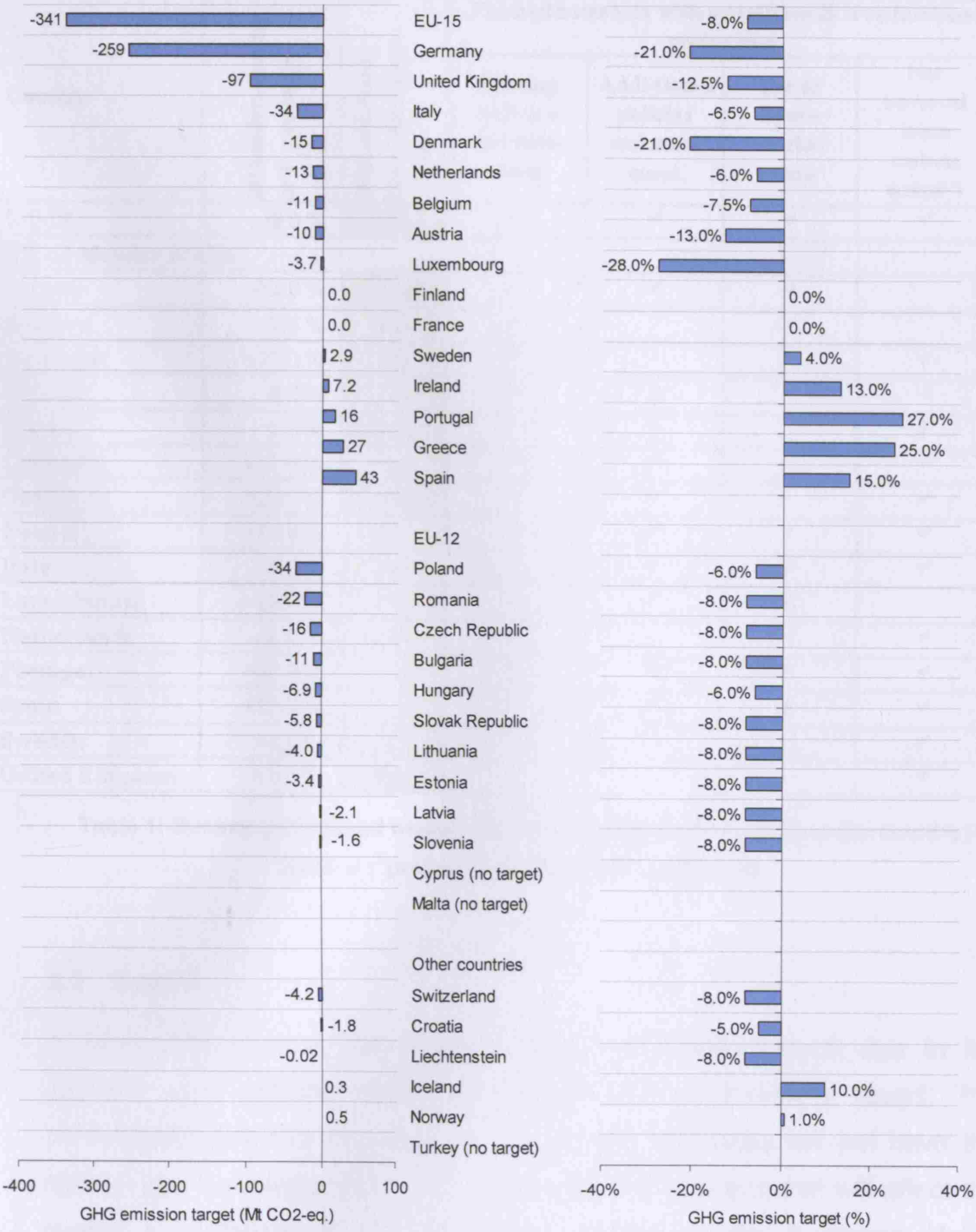
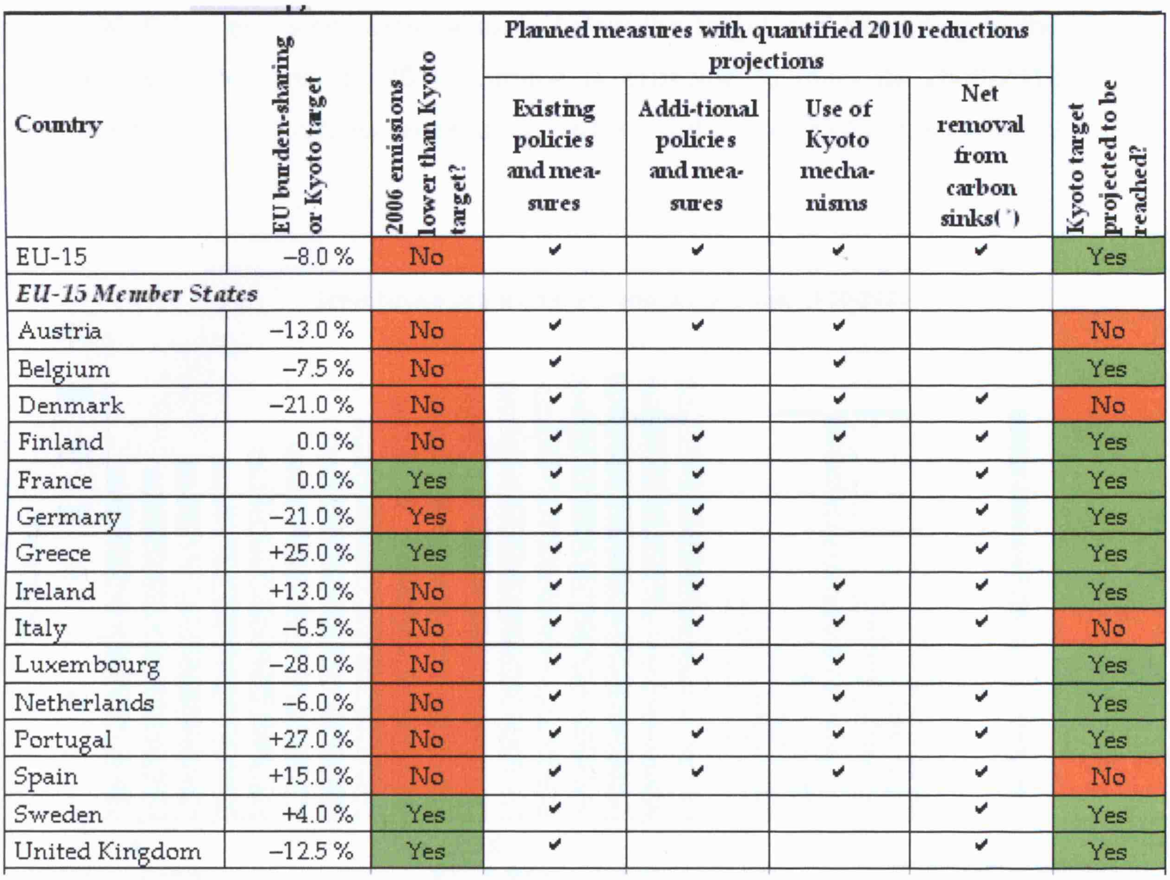


Figure 3: Greenhouse gas emissions target in Europe under the Kyoto Protocol (2008-2012) relative to base-year emissions (Source: EEA 2007b cited in EEA 2008, p. 34)



Country	EU burden-sharing or Kyoto target	2006 emissions lower than Kyoto target?	Planned measures with quantified 2010 reductions projections				Kyoto target projected to be reached?
			Existing policies and mea-sures	Addi-tional policies and mea-sures	Use of Kyoto mecha-nisms	Net removal from carbon sinks(*)	
EU-15	–8.0 %	No	✔	✔	✔	✔	Yes
EU-15 Member States							
Austria	–13.0 %	No	✔	✔	✔		No
Belgium	–7.5 %	No	✔		✔		Yes
Denmark	–21.0 %	No	✔		✔	✔	No
Finland	0.0 %	No	✔	✔	✔	✔	Yes
France	0.0 %	Yes	✔	✔		✔	Yes
Germany	–21.0 %	Yes	✔	✔		✔	Yes
Greece	+25.0 %	Yes	✔	✔		✔	Yes
Ireland	+13.0 %	No	✔	✔	✔	✔	Yes
Italy	–6.5 %	No	✔	✔	✔	✔	No
Luxembourg	–28.0 %	No	✔	✔	✔		Yes
Netherlands	–6.0 %	No	✔		✔	✔	Yes
Portugal	+27.0 %	No	✔	✔	✔	✔	Yes
Spain	+15.0 %	No	✔	✔	✔	✔	No
Sweden	+4.0 %	Yes	✔			✔	Yes
United Kingdom	–12.5 %	Yes	✔			✔	Yes

Table 1: Summary of planed measures and progress towards targets (by country)

Note: ✔ : projected (Source: EEA 2008, p. 9)

2.3 Greece

In April 2008 Greece was excluded from the Kyoto protocol due to the absence of a reliable monitoring system for the emissions report. The consequences of this exclusion are that Greek industries will not have the right to use the mechanisms of the protocol. This is a fact that will affect the overall performance of the emission's system of the European Union (Wikipedia 2008b). However, within EU-15, Greece intends to accomplish its Kyoto targets without the use of their government's Kyoto mechanisms although carbon allowances have been bought from the country under the EU emissions trading scheme (EEA 2008, p. 40).

In 2006 the emissions were already below the target and according to the national projections for 2010, Greece is expected to meet its 2008-2012 targets through policies, measures carbon sinks and Kyoto mechanisms (Figure 4).

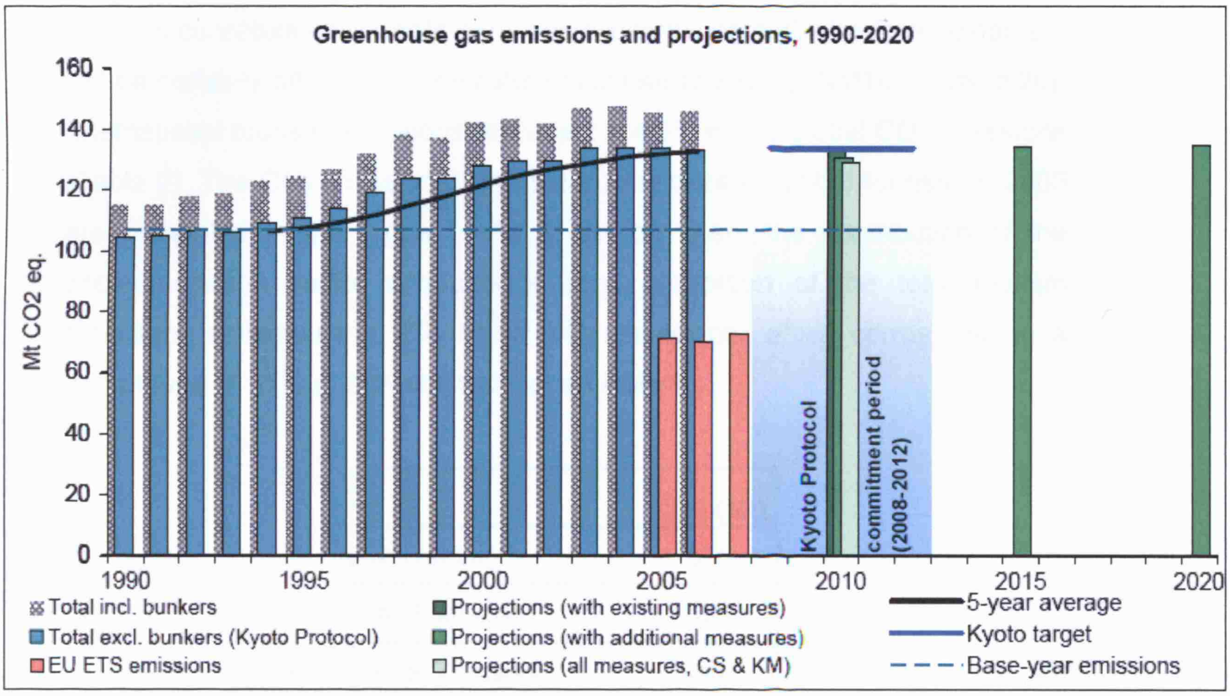


Figure 4: Greenhouse gas emissions and projections for Greece, 1990-2020, where: CS the use of carbon sinks and KM the use of Kyoto mechanisms (Source: EEA 2008)

2.4 Emissions and Tourism

Since climate change affects human's health and lifestyles, global economy and social relations, its consequences to these different sectors in all the nations around the world need to be addressed.

Tourism constitutes a "climate-sensitive economic sector" whose development will be certainly affected by the risks of climate change (UNMTO 2008, p.26). International tourism emissions represent a 4,9% of the global CO_2 emissions (Table 2). The CO_2 emissions from the sub-sectors of global tourism in 2005 are presented in the figure 5. As it can be seen, the contribution of the accommodation sector accounts a large proportion of the total tourism emissions accumulating 274 Mt of CO_2 emissions, which correspond to a percentage of 21% of the total tourism emissions.

	CO2 (Mt)
Air Transport	515
Car Transport	420
Other Transport	45
Accomodation	274
Activities	48
TOTAL	1.302
TOTAL WORLD	26.400
Share (%)	4,9

Table 2: Estimated emissions from global tourism (including same-day visitors), 2005 (Source: UNMTO 2008, p.33 Table 6.1)

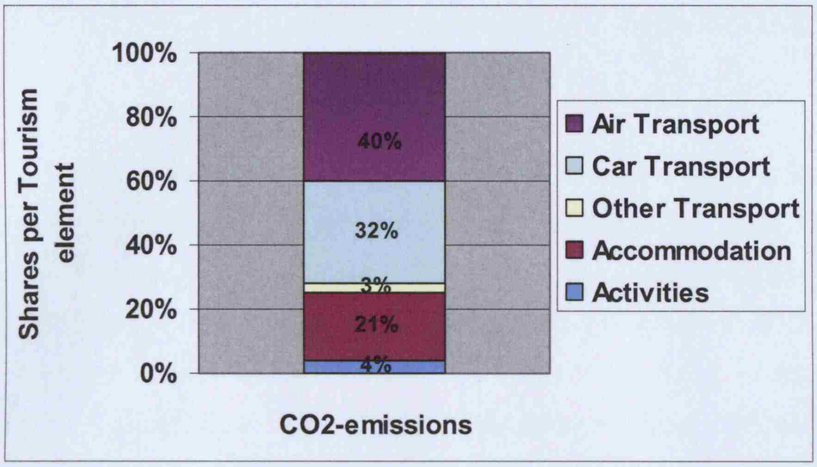


Figure 5: Contribution of various tourism sub-sectors to CO2 emissions (%) (Source: UNWTO 2008, p. 34 fig. 6.3)

There are several accommodation categories. However, this study will focus in the hotel sector. The global average emissions per guest night for hotels are 20,6 kg CO_2 which correspond to energy use per guest night in 130 MJ (Gossling 2002 cited in UNWTO 2008, p. 130).

CHAPTER 3

3 HELLENIC HOTELS & SUSTAINABILITY OPPORTUNITIES

3.1 The hotel sector in Greece:

Tourism in Greece constitutes one of the most important sectors in the Greek economy, contributing 15% to the nation's GDP (Wikipedia 2008c). Tourism policy is recently being encouraged in a National, European and International level for the improvement of provided services, and the adoption of alternative forms of tourism, such as ecotourism, which are in general friendly to the environment (Karagiorgas 2003 cited in Karagiorgas et al 2006). Tourism comprises of a wide variety of sub-categories one of which is the tourist accommodation sector including hotels. Hotels are among the greatest of the sub-sectors of tourism.

According to the National Statistical Service of Greece (NSSG), the total number of hotels in Greece in 2006 amounted to 9.111 with approximately 963.300 beds (NSSG 2006). The increase of new hotel unit construction in cities and islands is approximately 5% per year (Santamouris et al 1996). The majority of the Greek hotels (82%) have less than 50 rooms while the minorities of hotels have between 50 and 150 rooms (Figure 6). Concerning the guest type, a percentage of 64% are tourist seasonal hotels operating in the summer usually situated in islands whereas the remaining 36% are business hotels located in city centres (CHOSE 2001, p.16).

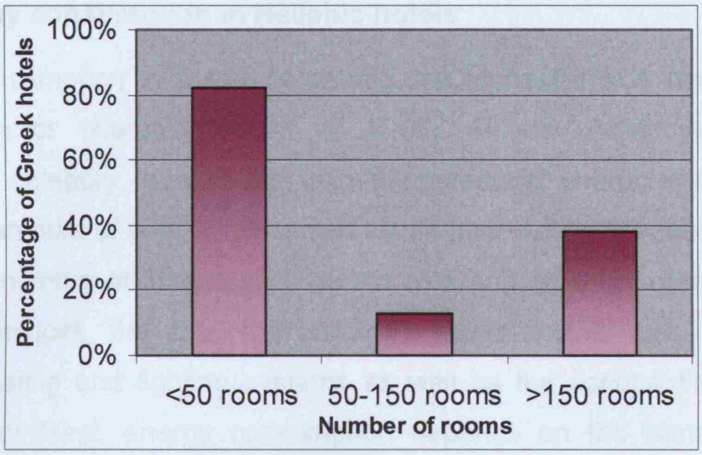


Figure 6: Classification of Greek hotels according to their number of rooms (Source: CHOSE 2001)

Hotels are separated in six categories according to certain standards they achieve. The most common category of Greek hotels are medium class hotels making 70% of the market (including three and four star hotels), while the luxury-high category (equal and more than five stars) constitute the minority of 10% of the Greek hotels (CHOSE 2001, p.19) (Figure 7) (Appendix A).

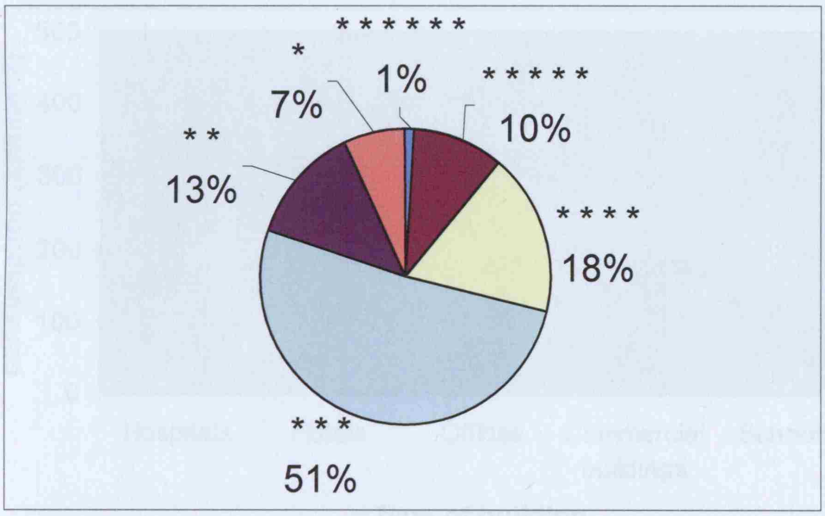


Figure 7: Classification of Greek hotels according to their category (source: Green lodges 2008)

3.2 Energy consumption in Hellenic hotels

Energy consumption in hotels is among the highest in the non-residential building sector (Karagiorgas et al 2006). Hotels constitute a distinct consuming category, due to the unique operational characteristics of their units. The amount of energy consumed within their buildings varies depending on a large number of factors such as the type and category of the hotel, the provided services, the size, the building's fabric and its age, the existing cooling, heating and lighting systems as well as the occupant's behaviour. Last but not least, energy consumption depends on the climate and the geographic location of the hotel (CHOSE 2001, p.6).

According to an energy audit that was carried in 158 Hellenic hotels, the annual average energy consumption in hotels was found to be 273 kWh/m^2. Hotels obtain the second place between hospitals (406,8 KWh/m^2) and office buildings (187 KWh/m^2) in energy consumption. Commercial buildings (152 kWh/m^2) and schools (92 kWh/m^2) obtain the third and fourth position respectively (Santamouris et al 1996) (Figure 8).

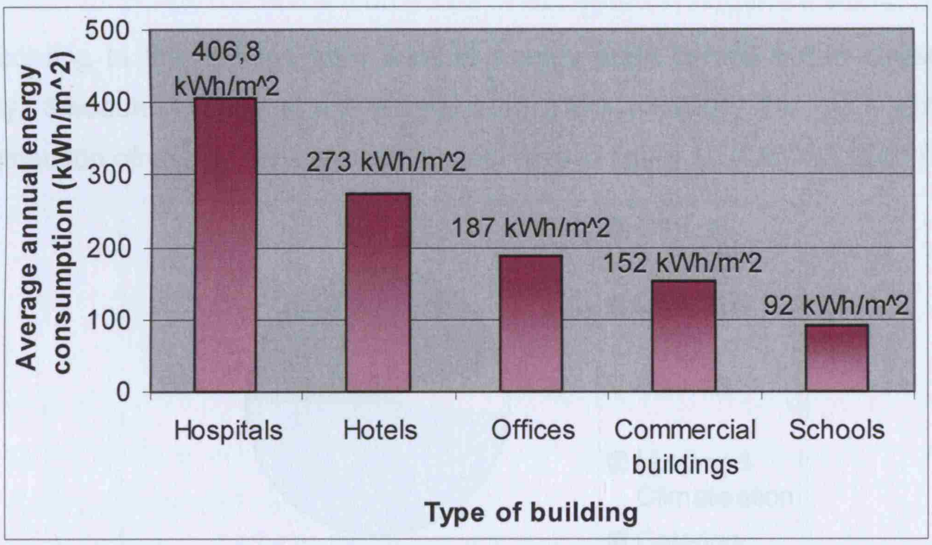


Figure 8: Average annual total energy consumption (kWh/m^2) in different categories of audited Hellenic buildings (Source: Santamouris et al 1996)

According to the same energy audit for hotels, the majority of energy is being consumed for heating purposes accounting 197,7 kWh/m^2 while for cooling only 10,7 kWh/m^2 are consumed. For lighting and electrical equipment 24,5 kWh/m^2 and 39,9 kWh/m^2 are consumed respectively (Figure 9).

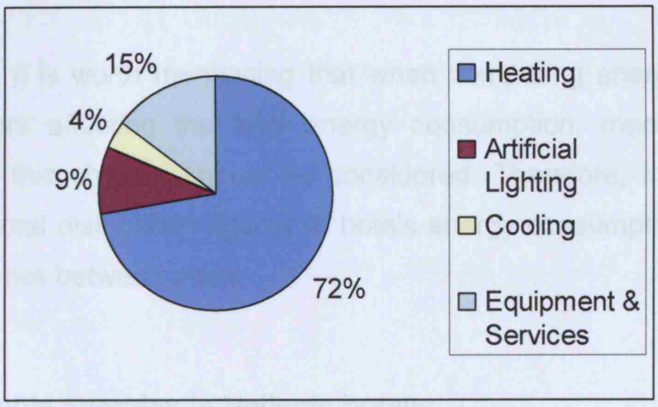


Figure 9: Break down of the energy consumption of 158 Hellenic hotels (Source: Santamouris et al 1996)

At this point it should be highlighted that the majority of the aforementioned hotels used as sample in this audit are located in the city of Athens.

According to the findings from another energy audit carried out in Greece, Italy, Sweden, Cyprus and Portugal from 1999 to 2001, the generalized distribution of energy consumption is presented in figure 10 (CHOSE 2001).

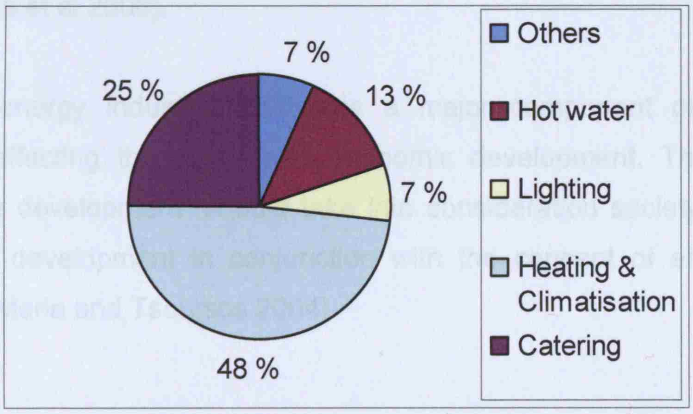


Figure 10: Distribution of energy consumption in hotels (Source: CHOSE 2001, p.7)

Figure 10 presents that heating and cooling is now accounting nearly half of the total energy consumption while for catering a percentage of 25% is being consumed. Lighting remains in rather same levels for both of the aforementioned audits collecting about 8% of the total energy consumption in the hotel sector.

At this point, it is worth mentioning that when comparing energy audits, the various factors affecting the total energy consumption, mentioned at the beginning of this chapter should be considered. Therefore, it is difficult to arrive at general distribution figures of hotels energy consumption due to the large differences between them.

3.3 Renewable energies in Hellenic hotels:

As aforementioned tourism industry is one of the most dynamic areas within the services sector including hotels which constitute very high energy consumers in the tertiary building sector. In order to face the continuously increasing energy demand during the tourist period, EU and the international tourist policy aim at encouraging the improvement of the environmental performance of services and products. The introduction of environmentally friendly technologies such as renewable energy technologies which will be less harmful to the environment than convectional energy sources (Karagiorgas et al 2006).

Moreover, energy industry constitutes a major component of the global economy, affecting the social and economic development. Therefore, the "sustainable development" should take into consideration society needs and economical development in conjunction with the concept of environmental protection (Maria and Tsoutsos 2004).

Moreover, the Mediterranean region presents ideal conditions for the application of solar energy technologies due to the excessive amount of solar radiation it receives every year, especially during the tourist period of mid-April until mid-October. In Greece the amount of receiving solar energy is approximately 8,4% of its total energy consumption (Moia- Pol et al n.d.). The highest amount of energy consumed by the hotel sector is used for thermal applications, and especially for heating and cooling. The utilization of solar power for water heating and HVAC can reduce the fuel consumption by 20 to 40% and therefore minimize CO_2 emissions (Moia-pol et al n.d.). To summarize, the optimum scenario of energy efficiency can be achieved if a balanced relationship between provided comfort for hotel occupants and energy consumption is obtained.

Finally, as mentioned in chapter 2.4, the contribution of hotels to the global carbon dioxide emissions is significant. The introduction of RES and the adaptation of energy efficient techniques in the hotels will result in stabilization or even reductions in the CO_2 emissions which will in turn decrease environmental hazards and will therefore lead the country to meet the Kyoto protocol's target. Furthermore, new working positions will be created with the introduction of new technology. To summarise, the benefits arising from RES and energy conservation measures, are social, economical and environmental (Diakoulaki et at 2001).

CHAPTER 4

4 THERMAL COMFORT CONDITIONS

4.1 Introduction:

Hotel units are used either for holidays or for business purposes and constitute an escapement from everyday life. They are built with view to provide exceptional stay to visitors, by providing rest and comfort. High levels of indoor thermal comfort play a significant role on the customer's satisfaction. Therefore, a pleasant thermal environment constitutes one of the key priorities issues that a hotel managing director should primarily address.

4.2 Thermal Comfort:

According to ASHRAEs definition, thermal comfort is "that condition of mind that expresses satisfaction with the thermal environment" (ASHRAE 1992). Thermal comfort constitutes a thermal equilibrium with the surrounding environment. Any additional loss or gain beyond this temperature level, can lead to a sensation of discomfort. Thermal comfort depends on the following personal and environmental parameters:

Environmental factors:

- Air temperature,
- Mean radiant temperature,
- Relative humidity,
- Air movement/ velocity,
- Climatic and seasonal variations,
- Building's design, including the level and type of insulation, the glazing elements and in general, the building's thermal resistance.

Personal factors:

- Level of activity a man carries,
- Thermal resistance of its clothing,
- Age, sex and the degree of fitness of the individual (HSE1999),
- Time the person is exposed to the hot-cold environment,
- Thermal adaptation ability of individuals, due to the climatic variety of geographical regions.

Criteria for an acceptable thermal indoor climate are specified as requirements for general thermal comfort. International guidelines and standards on the measurement, assessment and evaluation of the thermal environment have been developed by ASHRAE, EN ISO 7730, CR 1752 and CIBSE (Olesen n.d). The recommended temperature bands of CIBSE's in hotel buildings are presented in table 3 (CIBSE, Guide A 2006):

	Winter			**Summer**		
Room Type	**Temp (oC)**	**Activity/ met**	**Clothing/ clo**	**Temp (oC)**	**Activity/ met**	**Clothing/ clo**
Bedrooms	19-21	1	1	21-23	1	1,2
Library reading room	22-23	1,1	1	24-25	1,1	0,65
Office executive	21-23	1,2	0,85	22-24	1,2	0,7
Corridors	19-21	1,4	1	21-23	1,4	0,65
Lobbies/ Waiting areas	19-21	1,4	1	21-23	1,4	0,65

Table 3: Recommended comfort criteria for specific applications (Source: CIBSE, Guide A 2006, p. 17 table 1.5)

The clothing values concern the thermal insulation values for typical clothing during the two seasons and the metabolic heat production associates to the level of activity a man carries (CIBSE, Guide A 2006, p. 13).

Dr Ole Fanger proposed a method in order to predict the actual thermal sensation. This was the Predicted Mean Vote (PMV) model in which the influence of the different variables such as temperature, humidity, air speed, activity and clothing, are merged into a single thermal sensation scale. The PMV comes from a large sample of people that are exposed into the same environment, are wearing the same clothing and are carrying the same activity (CIBSE, Guide A 2006, p.11) (Appendix B). The Predicted Mean Vote (PMV) as a function of the Predicted Percentage Dissatisfied (PPD) is presented in figure 11 (CIBSE, Guide A 2006, p.13).

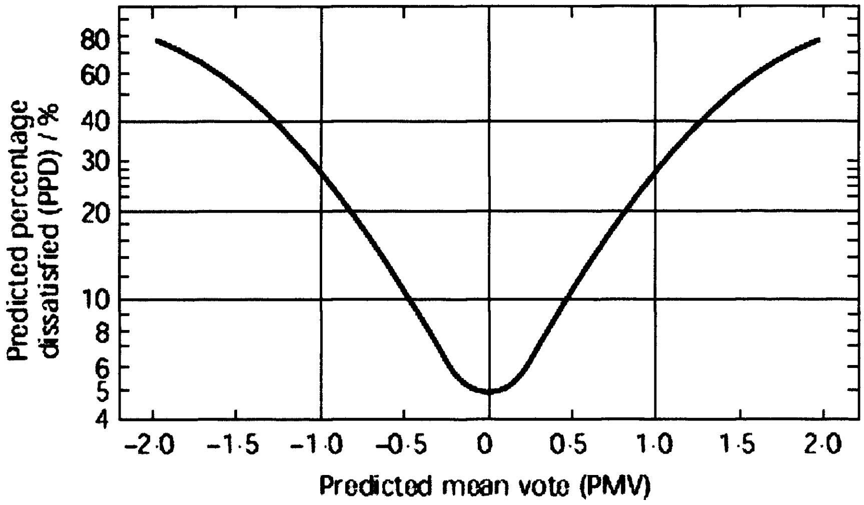


Figure 11: Relationship between PPV and PMV (Source: CIBSE, Guide A 2006, p.13)

The thermal comfort scale as defined by ASHRAE and Bedford is presented in table 4. Responders have voted their expression on thermal comfort satisfaction according to the psycho-physical scale by the two organizations.

ASHRAE	Predicted mean vote (PMV)	BEDFORD
Hot	-3	Much too warm
Warm	-2	Too warm
Slightly warm	-1	Comfortably warm
Neutral	0	Comfortable neither warm nor cold
Slightly cool	1	Comfortably cool
Cool	2	Too cool
Cold	3	Much too cool

Table 4: Thermal comfort scale of ASHRAE and Bedford (Source: Nicol & Humphreys 2002 and Mc Intyre 1980)

The PMV model corresponds to buildings with HVAC systems. However, several studies of de Dear and Brager (1998) show that in naturally ventilated buildings occupants accept higher internal temperatures than the ones predicted from the predicted mean vote (PMV) model (Olesen n.d.). This is called adaptive approach of thermal comfort in the built environment and associates with the occupant's behavioural and psychological adaptation, and acceptance of higher indoor temperatures which will be further analysed.

4.3 The adaptive model of thermal comfort:

According to de Dear and Brager (1998) the concept of adaptive approach to thermal comfort assigns the occupants to "play an active role in creating their own thermal preferences" rather than being passive receivers of the internal thermal conditions of the building (de Dear and Brager 2001) (Appendix C). Therefore, they introduced the effect of varying outdoor temperatures to the determination of accepted thermal limits. Thus, acceptable indoor temperatures for naturally ventilated buildings should be modified according to the mean monthly outdoor air temperatures and the human's ability to adapt (CIBSE, Guide A 2006, p.26).

4.4 Setting environmental targets and benchmarks:

4.4.1 Temperatures:

The temperature's benchmarks corresponding to thermal acceptability ratings of 90% and 80% are presented in figure 12. The linear equations which give the respective limits of optimum comfort according to the adaptive model are the following (de Dear and Brager 2001):

Comfort temperature (°C) = 0.31 (mean outdoor monthly air temperature) + 17.8
Upper 90% acceptable limit (°C) = 0.31 (outdoor air temperature) +20.3
Lower 90% acceptable limit (°C) = 0.31 (outdoor air temperature) +15.3
Upper 80% acceptable limit (°C) = 0.31 (outdoor air temperature) +21.3
Lower 80% acceptable limit (°C) = 0.31 (outdoor air temperature) +14.3

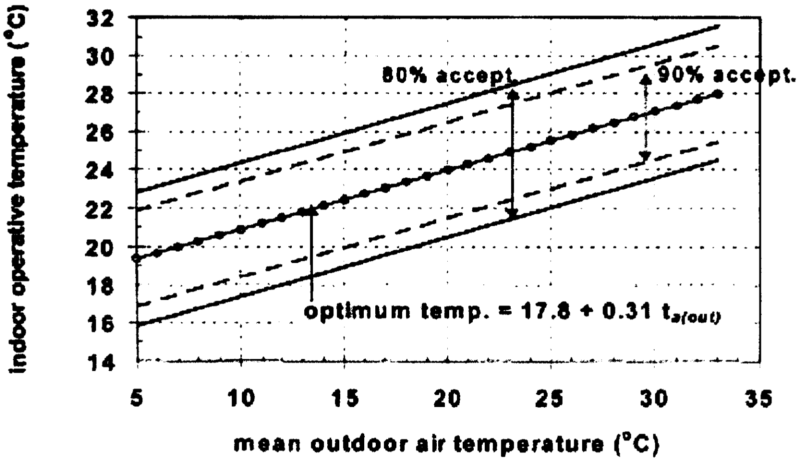


Figure 12: The adaptive comfort standard in naturally ventilated spaces as a function of prevailing outdoor air temperature (Source: de Dear and Brager 2001)

According to the external temperatures of the case study location, taking into account the aforementioned formulas of the adaptive approach, the following benchmarks are determined (Table 5) (Appendix D):

Thermal comfort	Temperature benchmarks (oC)
	High- Season June-July-August
80% Acceptability	22-29
90% Acceptability	23-28

Table 5: Temperature benchmarks according to the external temperatures of Kefalonia

CHAPTER 5

5 CASE STUDY: "Sami Beach Hotel", KEFALONIA

Based on the analysis of the energy consumption of Hellenic hotels that was described in the chapter 3, the case study of the hotel "Sami Beach" in Kefalonia will be examined closely in this part. This chapter describes the location of the building, its existing construction and the outdoor prevailing weather conditions.

5.1 Location, the island of Kefalonia:

Kefalonia, is the largest island of the Ionian cluster in western Greece, and sixth in size in the entire country, with a total surface area of 906,5 km^2 a coastline of 254 km and population of approximately 32.000 inhabitants (Greek islands 2008) (Figure 13).

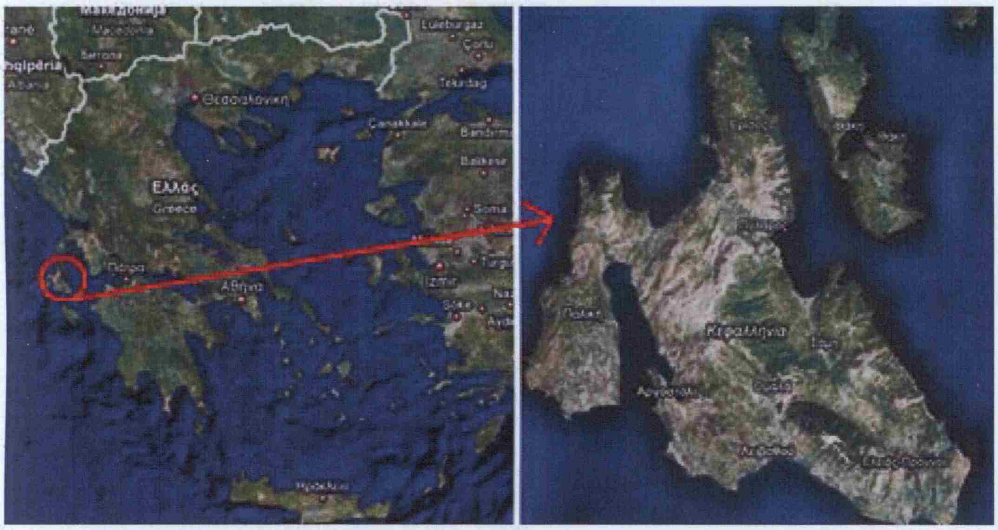


Figure 13: Map of Greece, location of Kefalonia (Source: Google maps 2008)

Kefalonians main occupations are fishing, agriculture, and winery. Last but not least, a great percentage of the island's economy is based on tourism.

Because of the island's natural beauties, beaches, caves and geological phenomena, in combination to the Mediterranean Climate, Kefalonia constitutes one of the most popular destinations attracting thousands of tourists every year (Kefalonitis 2008).

According to the National Statistical Service of Greece (NSSG), the percentage of occupancy of hotels in Kefalonia for the year 2006 was 65.1-75% (Figure 14) (NSSG 2008).

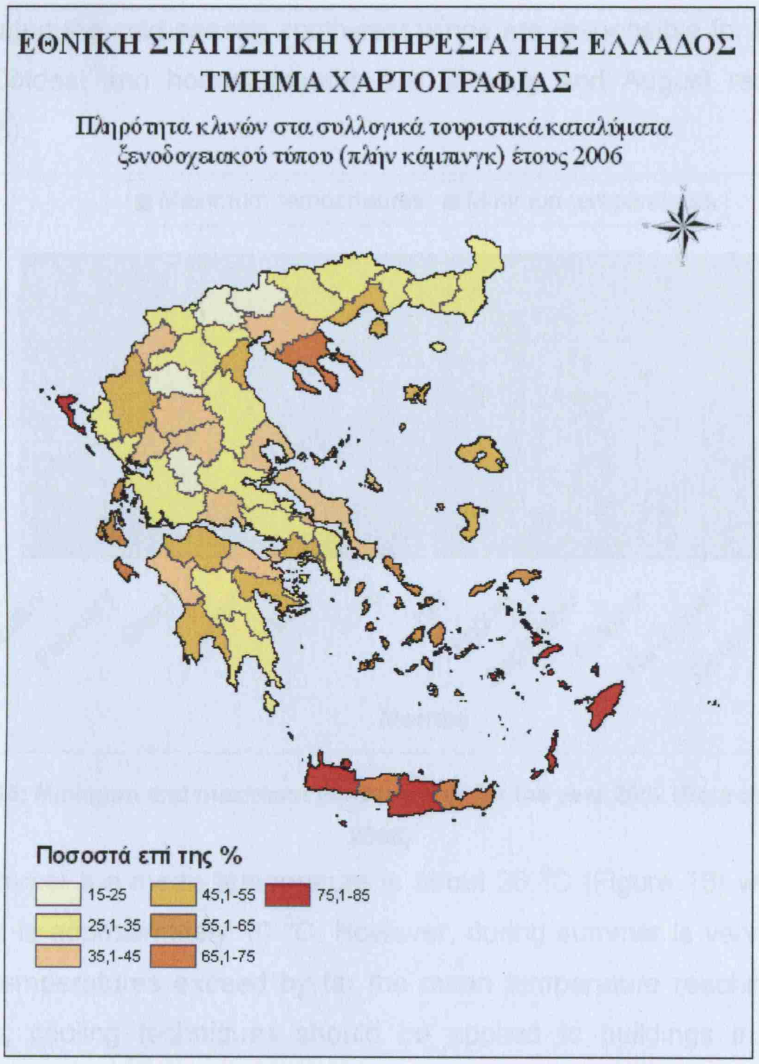


Figure 14: Occupied beds in Greek hotels for the year 2006 (Source: NSSG 2008)

5.2 The climate of Kefalonia:

Greece has a typical Mediterranean climate characterized by mild winters, relatively warm and dry summers and extended periods of sunshine throughout the entire year. In the several regions of Greece a variety of sub-climates are observed because of the influence of topography on the air coming from the Mediterranean Sea (HNMS 2008).

In particular, the island of Kefalonia in the Ionian Sea is characterized by rather mild winters and cool summers. As regards the winds blowing in the island, during the cold season southwest winds are responsible for the heavy rainfall. Coldest and hottest months are January and August respectively (Figure 15).

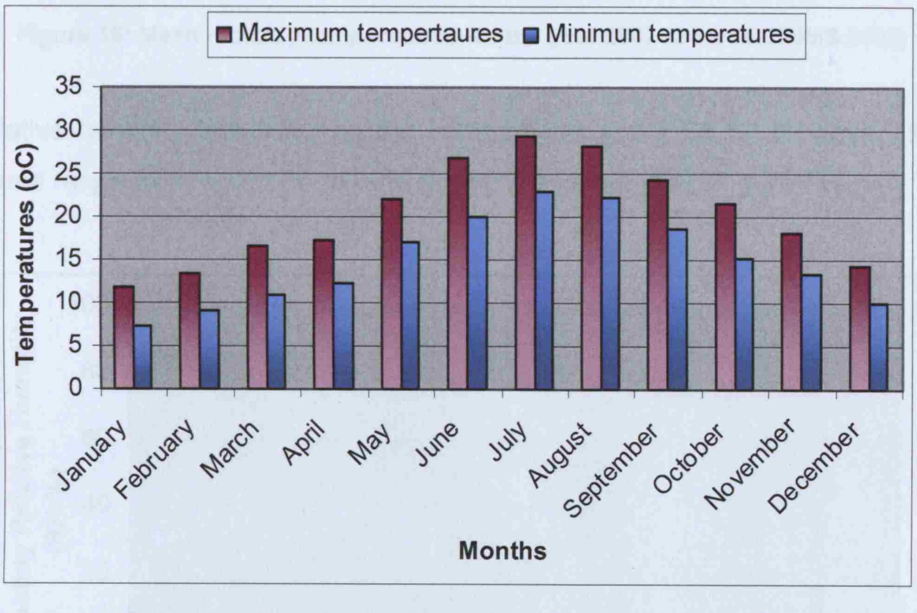


Figure 15: Minimum and maximum temperatures for the year 2002 (Source: HNMS 2008)

In the summer the mean temperature is about 26 ^{0}C (Figure 16) whereas in the winter is approximately 10 ^{0}C. However, during summer is very common that the temperatures exceed by far the mean temperature reaching 35 ^{0}C. Therefore, cooling techniques should be applied to buildings in order to achieve adequate levels of temperatures.

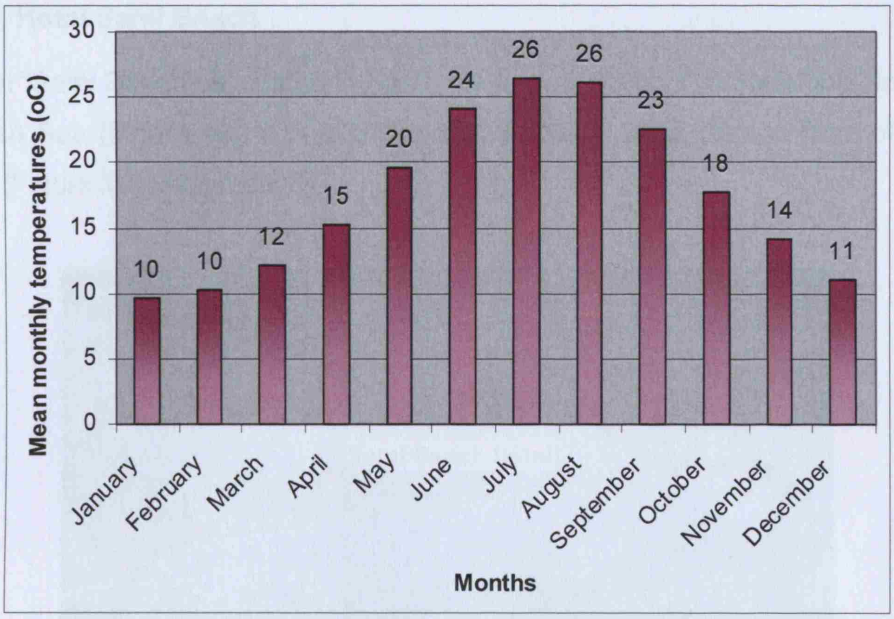


Figure 16: Mean monthly temperatures for the year 2002 (Source: HNMS 2008)

Relative humidity levels during the summer are about 65 %. However, their values range from about 60 to 80% during the whole year (Figure 17).

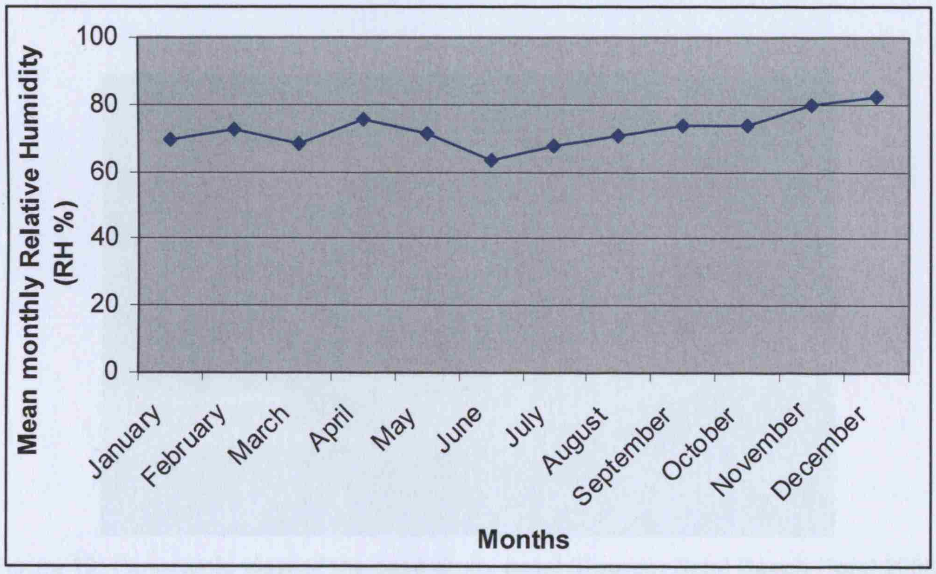


Figure 17: Mean monthly relative humidity for the year 2002 (Source: HNMS 2008)

5.3 Hotel Sami Beach

Hotel "Sami Beach" is located in Sami, the largest harbour, of Kefalonia, in the Ionian Sea (Figure 18). It is a situated at a coastal area, 30m in front of the sea (Figure 19) (Appendix E).

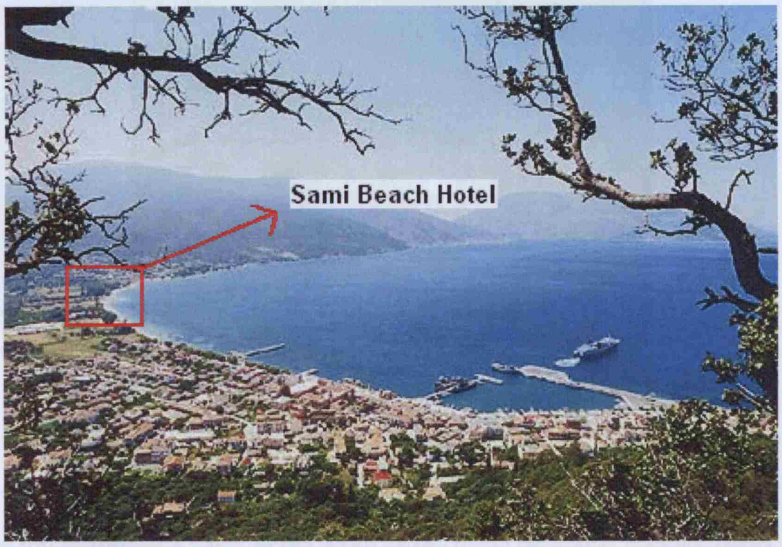


Figure 18: The harbour of Sami, Kefalonia (Source: Travel to Kefalonia 2008)

Figure 19: Panoramic view of the case study hotel (Source: Sami Beach Hotel 2008)

The hotel is facing North from its main façade (Figure 20), where is overlooking the sea and there aren't any buildings surrounding it (Figures 21). The hotel was built in the late 80s influenced by the traditional architecture of Kefalonia before the catastrophic earthquake of 1953.

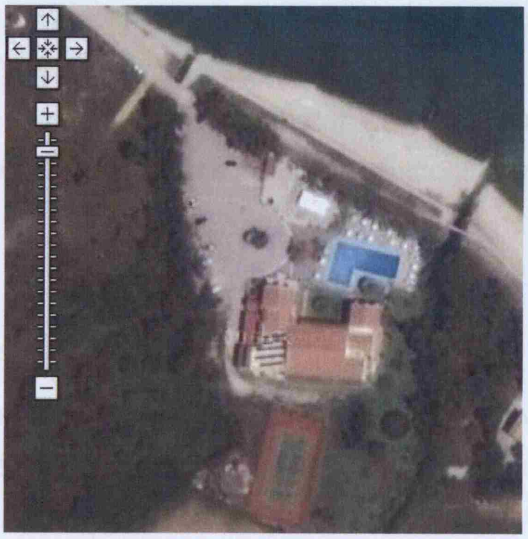


Figure 20: Panoramic view of the case study hotel (Source: Google maps 2008)

Figure 21: Panoramic view of the case study hotel (Source: Sami Beach hotel 2008)

Hotel Sami Beach is a B category hotel (three star) operating seasonally (May to mid- October) and therefore consisting a tourist type of hotel. It has 44 double rooms in total, split in two floors with an average area of each room of about 20 m^2 and a total floor area of 1.400 m^2.

The electrical appliances within each room are; an air conditioning unit, a ceiling fan, a refrigerator and a television. Since it is a seasonal hotel operating in the summer, it is obvious that the air conditioning units are only used for cooling. Additional facilities include an outdoor swimming pool, a pool bar and breakfast.

5.4 Monitoring actual conditions

In order to assess how the room temperatures respond to the external weather conditions, sensors monitoring internal and external conditions were placed in and out of the building (HOBO 2008).

The rooms that have been selected to place the sensors are rooms which present opposite and extreme performances concerning indoor temperatures. Therefore, a North facing room in the ground floor (Figure 22) and a west facing room in the first floor (Figure 23) were monitored for a day.

Since the sample of the monitoring is relatively small, the results are not representative. However, the relative response to the external environment is rather clear. By comparing the following diagrams, it is obvious that the west facing room of the first floor is in average 0,7 ^{0}C warmer than the one in the ground floor as a precondition that the external temperatures perform similarly for the two days.

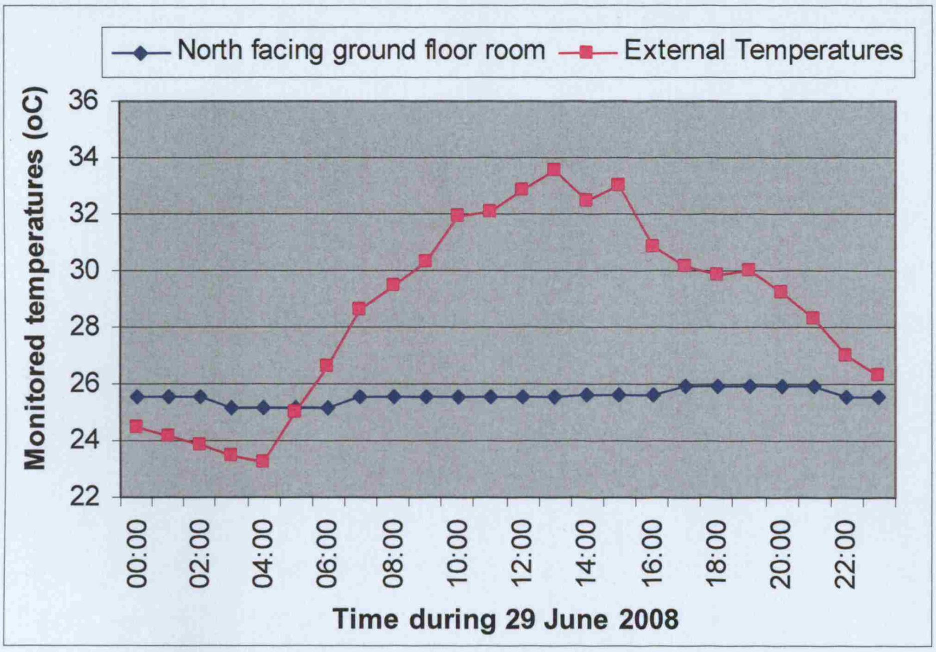


Figure 22: Monitored temperatures for a north facing room in the ground floor and corresponding external ones

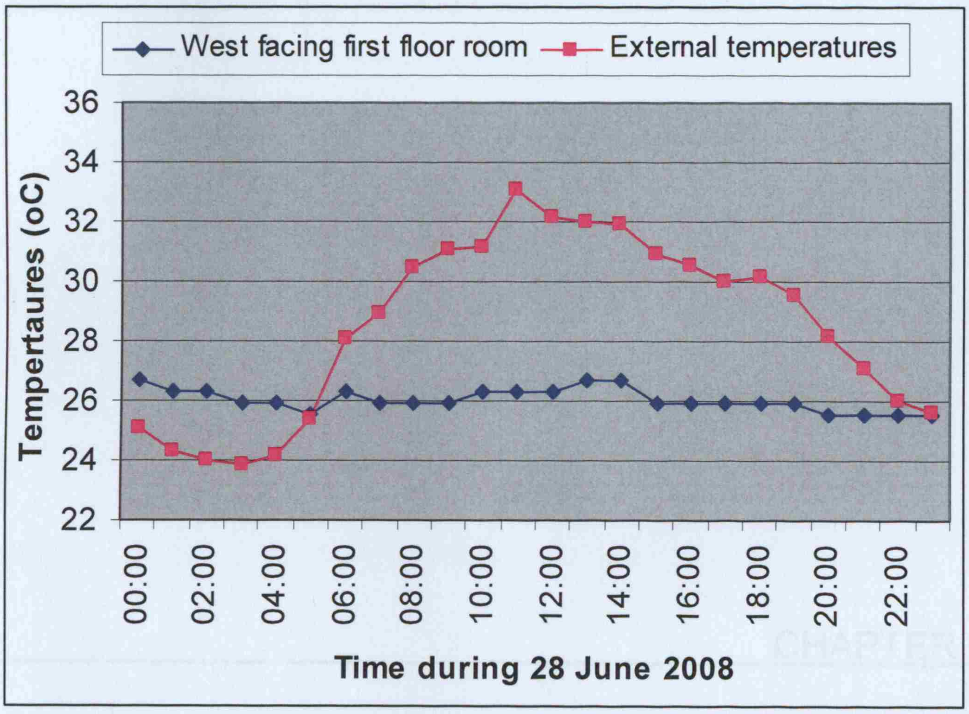


Figure 23: Monitored temperatures for a west facing room in the first floor and corresponding external ones

CHAPTER 6

6 CURRENT ENERGY CONSUMPTION- DATA GATHERING

In order to determine the potential energy savings, it is crucial to investigate where and how energy is being consumed within the building. Therefore, this chapter analyses the energy consumption of the case study hotel based on electricity and fuel bills. A detailed discussion concerning the cooling system, the methodology for hot water production and the general distribution of energy consumption will be developed.

6.1 Controls

Before analysing the hotel's energy consumption, is worth mentioning the controls that have already been installed to the building in order to reduce energy wastage. For instance, the electrical lighting of the rooms operates only whenever the rooms are occupied by a magnetic key system. Furthermore, to avoid conditioned air escaping through the windows, another magnetic system has been installed which allows the air conditioning to operate only when the windows are closed.

6.2 Operation of the heating and cooling system:

The air conditioning type of the hotel is a cooling centralized water system. The condenser and compressor are located at the outdoor plant area (Figure 24). The chillers use pipes, mounted within the suspended ceiling, to distribute chilled water in all of the rooms. Chilled water is carried within the occupied spaces by individual units; the fan coils (Figure 25). Occupants have the control for their individual units by adjusting the temperature according to their personal preference thermal levels through a thermostat placed in each room (Figure 26). The total conditioned floor area is 1.400 m^2.

Figure 24: Dry cooler

Figure 25: Room fan coils

Figure 26: Room thermostats

6.3 Hot water production:

Solar collectors are installed for the provision of water heating purposes including customer's needs, dishwashers as well as laundry facilities (Figure 27). "Sami Beach Hotel" uses 22 flat plate solar collectors of a total area of about 35 m^2. The produced hot water is being stored in two tanks with total capacity of 1.500 litres each (Figure 28). When the levels of sunlight are not sufficient, then the fuel oil burner starts automatically to operate as a back up system in order to maintain adequate water temperatures (Figure 29). The fuel consumed by the back- up system is fuel oil (petrol). According to energy audits, the total consumption of fuel oil (petrol) used for water heating during the operational months of the hotel for the year 2007(May to mid-October), was approximately 2.800 litres, which corresponds to approximately 32.732 kWh and 23,4 kWh/m^2 (Carbon Trust 2008).

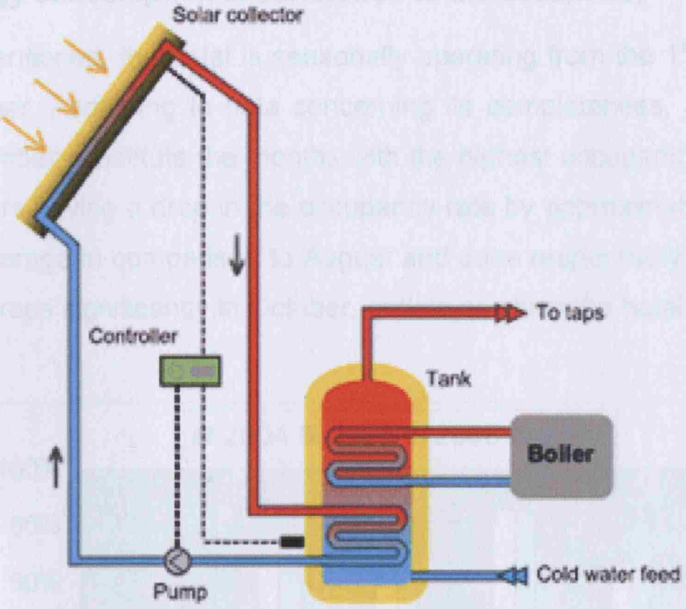


Figure 27: Solar collector (Source: Treco Green Heat 2008)

Figure 28: Hot water insulated storage tanks

Figure 29: Oil burner

6.4 Gas consumption

Facilities such as laundry dryer, ironing and staff's cooking are met by natural gas. The total amount of delivered gas to the hotels' doors for the operational period in 2007 was approximately 2.700 litres. This corresponds to an annual consumption of about 30 kWh (Carbon Trust 2008).

6.5 Energy consumption in correlation to the occupancy

As aforementioned, the hotel is seasonally operating from the 1st of May until mid- October. According to data concerning its completeness, June, August and September constitute the months with the highest occupancy (Figure 30). July appears having a drop in the occupancy rate by approximately 30 % and 20 % in average in comparison to August and June respectively. The number of clients drops significantly in October, middle of which the hotel shuts.

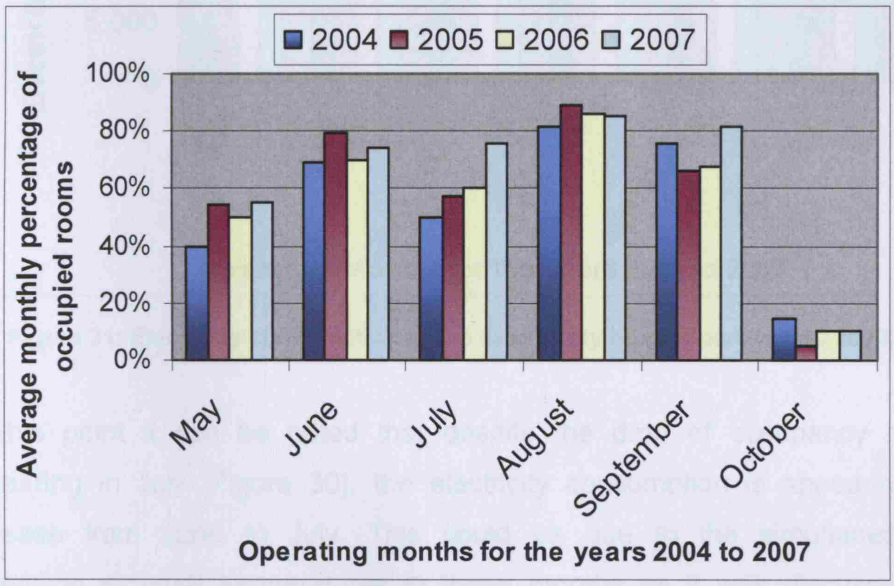


Figure 30: Occupancy rate for the case study hotel (Source: Occupancy records of Sami Beach hotel)

6.6 Electricity consumption

The electricity consumption concerns the electricity consumed for lighting, air conditioning purposes, and electric appliances within the hotel including refrigerators, freezers, televisions and motors for piping water. The following diagram indicates the electricity consumption of the hotel's operational months for the years 2004-2007. In average, an increasing tendency of electricity consumption is appearing from May to August, peaking in August (Figure 31).

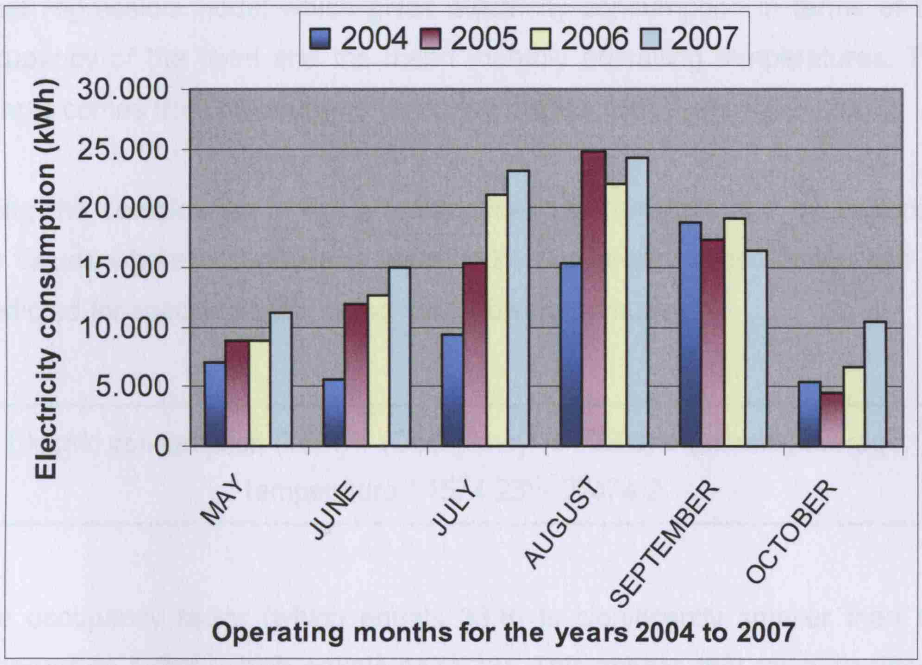


Figure 31: Electricity consumption of the case study hotel (Source: PPC 2008)

At this point it can be noted that despite the drop of occupancy rates appearing in July (Figure 30), the electricity consumption is appearing to increase from June to July. This could be due to the simultaneously increasing external temperatures in these months as it was discussed in previous chapter (5.2) and therefore the increasing demand for air conditioning use. The fact with the occurring peak in electricity demand during summer can be generalized for most developed countries due to the growing usage of air-conditioners (Papadopoulos et al 2003).

The increase of the electricity consumption can be further explained using a linear regression model which gives electricity consumption in terms of the occupancy of the hotel and the mean monthly prevailing temperatures. The sample comes from measurements during the last four years (2004-2007).

Using the combination of the aforementioned parameters and by excluding the values where occupancy is below 10% the energy consumption can be predicted for specific states, using the following formula:

Electric consumption (kWh) = (Occupancy % * 33.8) + (monthly average temperature * 1574.23) - 22474.2

The occupancy factor (which equals 33,8) is significantly smaller than the temperature factor (which equals 1574,23). This implies that for a significant occupancy increase, when the temperature remains in stable levels, the energy consumption would increase by a small amount. On the other hand, an increase by some Degrees in the temperature, for the same levels of occupancy would lead to a significant increase in the energy consumption.

Therefore, the conclusions arising from this study are that the temperature instead of occupancy is by far the most important parameter at determining the total energy consumption of the hotel. This can be justified since the occupancy is not a statistically significant factor meaning that the cooling system will operate regardless the occupancy levels. The following diagram can predict the electricity consumption given the occupancy and temperature rates with a statistical error equal to approximately 3% (Figure 32).

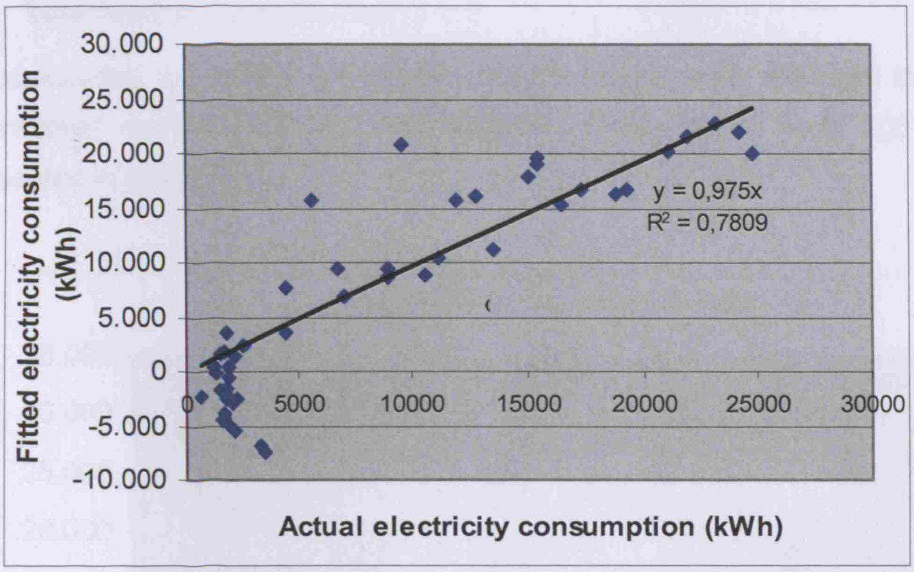


Figure 32: Predicted and actual electricity consumption

Further conclusions arising from this study are that the installation of controls that would adjust the cooling and lighting loads to the occupancy levels could lead in reductions of the electricity consumption.

6.7 Total energy consumption

Recapitulating, the energy consumed for each sector within the hotel for the operational months (May to mid-October) of the recent year 2007, is presented in figure 33.

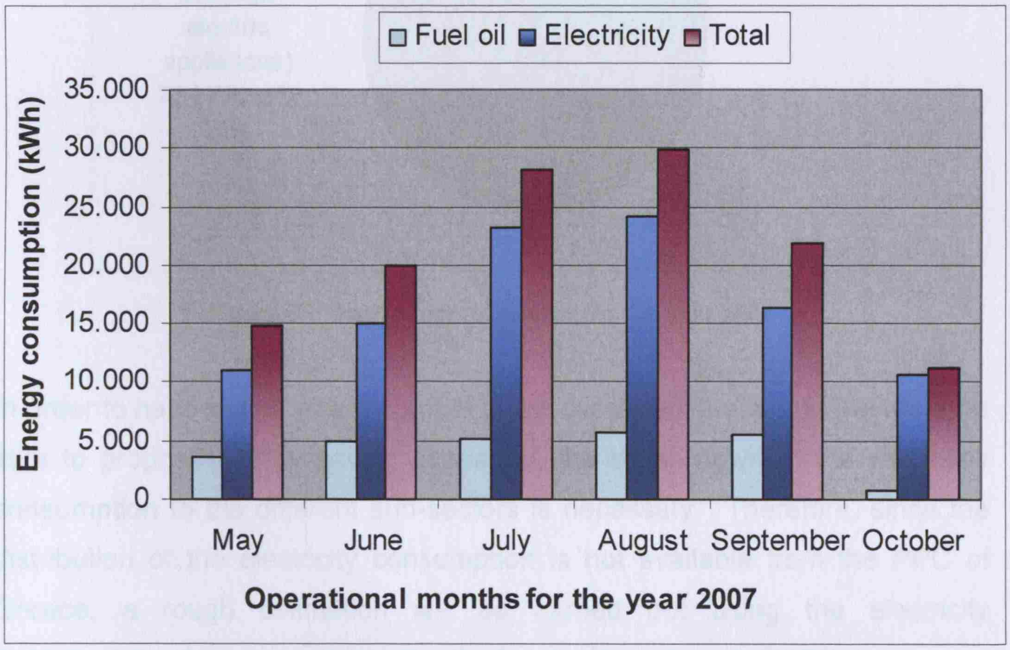


Figure 33: Distribution of energy for the year 2007

The electricity consumption cumulates three quarters of the hotel's total energy consumption (Figure 34) whereas fuel oil for water heating purposes collects 25% of the total energy consumption. The amount of natural gas (30 kWh per year) for cooking and laundry facilities collects a value smaller that 1% of the total consumption.

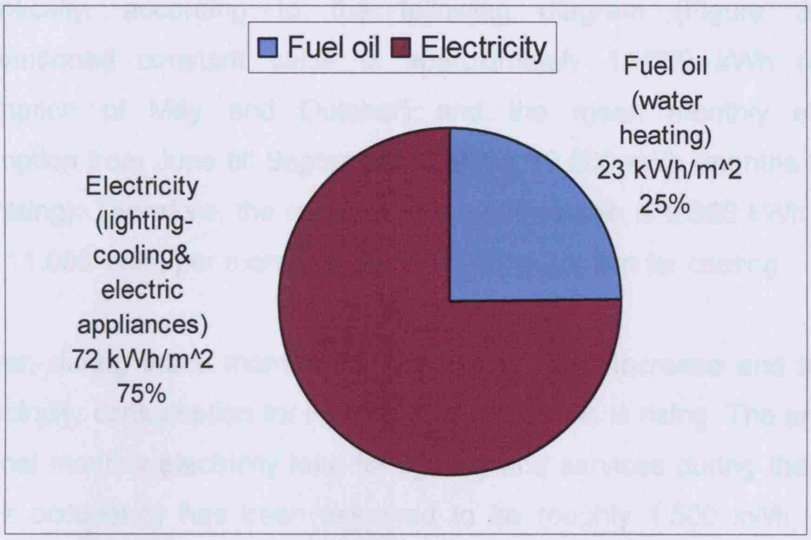


Figure 34: Distribution of energy for the year 2007

In order to have a clear energy profile of the case study hotel and therefore be able to propose energy saving scenarios, the break down of the electricity consumption to the different sub-sectors is necessary. Therefore, since the distribution of the electricity consumption is not available from the PPC of Greece, a rough estimation will be carried out using the electricity consumption of the operational months for a reference year (2007).

According to the facilities manager, the air conditioning starts to operate on the first of June and stops by the end of September. Therefore, the average electricity consumption of May and October covers lighting, electrical appliances and pumps. If this amount is considered as a benchmark, constant and fixed value which will be subtracted from the mean monthly electricity consumptions of the months while the air conditioning is operating (June to September), then the resulting value will concern the average monthly electricity consumption for cooling purposes.

Arithmetically, according to the following diagram (Figure 35), the aforementioned constant value is approximately 11.000 kWh (Average consumption of May and October) and the mean monthly electricity consumption from June till September is about 19.500 kWh (months that A/C is operating). Therefore, the result from the subtraction is 8.500 kWh (19.500 kWh – 11.000 kWh) per month of electricity consumption for cooling.

However, during these months the occupancy rates increase and therefore the electricity consumption for lighting and appliances is rising. The amount of additional monthly electricity load for lighting and services during the months of peak occupancy has been assumed to be roughly 1.500 kWh, a value which will be further subtracted from the previous resulting monthly value for cooling. Thus, using this rough estimation, the average monthly electricity consumed for cooling is 7.000 kWh, meaning that the cooling loads are approximately 28.000 kWh (20 kWh/m^2) per year (4 months of air conditioning operation).

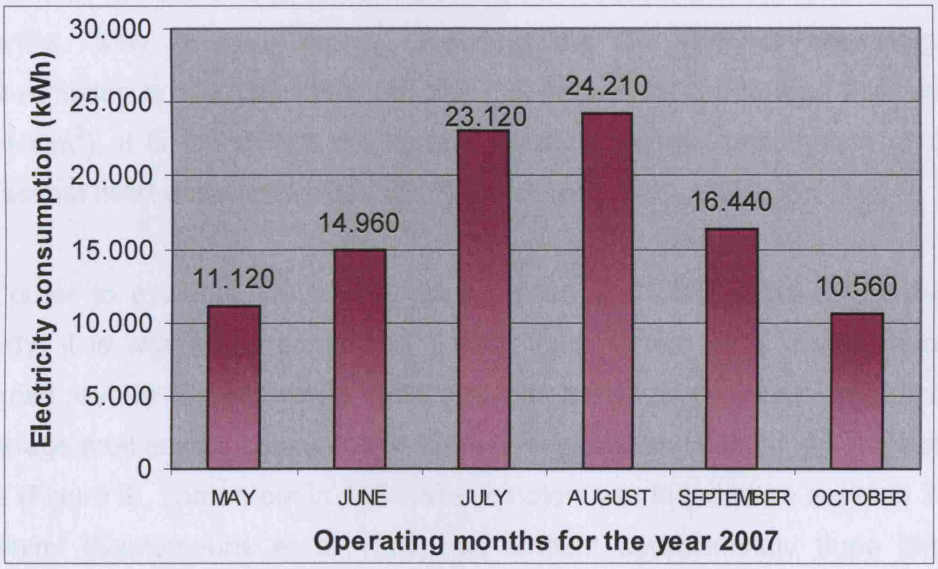


Figure 35: Electricity consumption for the operational months of the year 2007 (PPC 2008)

Therefore, the remaining 72.410 kWh (52 kWh/m^2) are being consumed for lighting, electrical equipment and services. Thus, the total distribution of energy for the case study is modulated as follows (Figure 36):

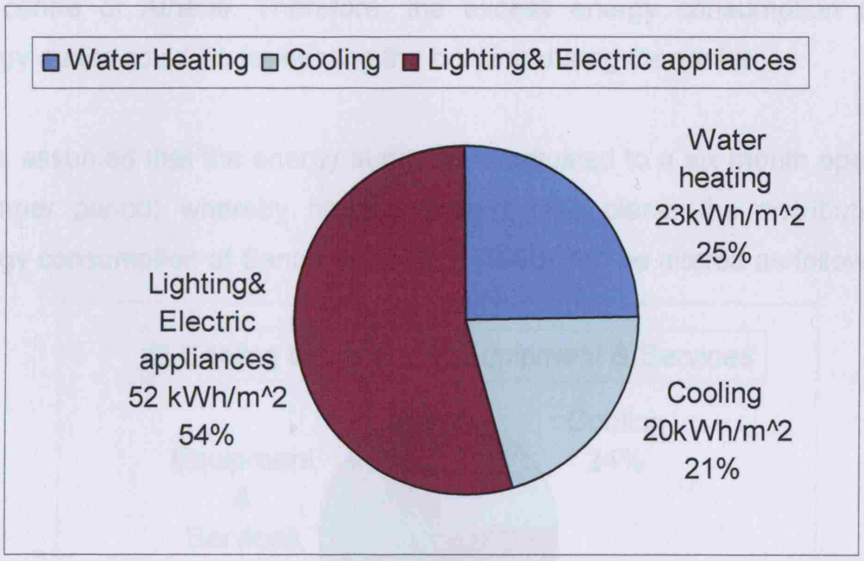


Figure 36: Modified distribution of energy consumption of the "Hotel Sami Beach"

The total annual energy consumption of the seasonal hotel (Operational months: May to mid-October) including the 30 kWh of natural gas consumption is **133.180 kWh**. Dividing this amount by the treated floor area (1,400m^2), it is found that the current average energy consumption of the seasonal hotel under investigation is **95 kWh/ m^2**.

In order to evaluate the energy consumption and distribution of the case study, it is worthwhile comparing it with findings from other energy audits carried out in Greek hotels mentioned in previous chapter. The annual average total energy consumption of the energy auditing mentioned in chapter 3.2 (Figure 9), carried out in 158 Hellenic hotels has found to be equal to 273 kWh/m^2 (Santamouris et al 1996), an amount approximately three times greater than the estimated one of the case study. A possible reason for this massive difference is due to the different operational periods and locations for the two cases.

The case study hotel only operates for five and half months a year and is located at an insular area, whereas the hotels of the energy audits concerned hotels operating all year round the great majority of which were located in the city centre of Athens. Therefore, the excess energy consumption of the energy audits could be for heating the building during the winter.

If it is assumed that the energy audits were adjusted to a six month operation (summer period) whereby heating doesn't take place, the distribution of energy consumption of Santamouris et al (1996) can be altered as follows:

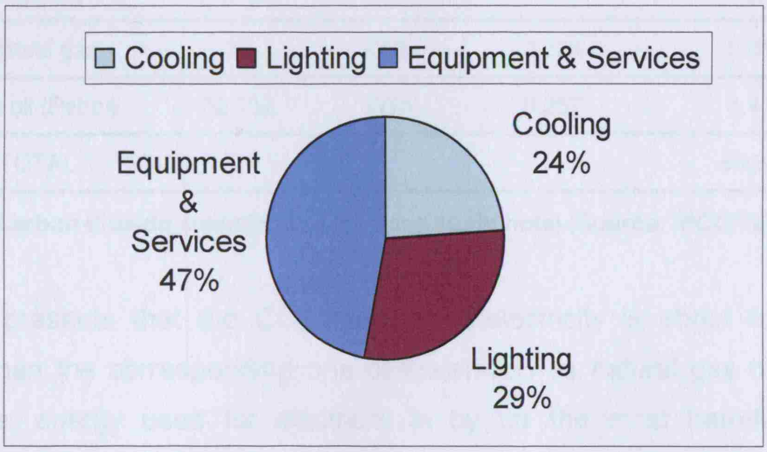


Figure 37: Modified energy distribution in 185 Hellenic hotels (Santamouris et al 1996)

By comparing the results presented in figures 36 and 37 someone could conclude that the percentage of energy consumption for cooling of the case study hotel might represent the percentage of energy used for cooling in a larger scale.

6.8 Case study: greenhouse gas emissions

Taking into account the total annual energy consumed in the case study hotel, the corresponding greenhouse gas produced, are presented in the following table:

Energy source	**Annual energy consumption (kWh)**	**Units**	**Carbon dioxide intensity of electricity & fuels for Greece**	**Carbon dioxide produced (tn CO2)**
Electricity	100.400	kWh	0,876	87,95
Natural gas	30	kWh	0,204	0,01
Fuel oil (Petrol)	32.732	kWh	0,257	8,41
TOTAL				96,37

Table 6: Carbon dioxide emissions of the case study hotel (Source: IPCC/TEAP 2008)

Table 6 presents that the CO_2 intensity of electricity is about four times greater than the corresponding one of fuels such as natural gas or fuel oil. Therefore, energy used for electricity is by far the most harmful to the environment. However, at this point it should be highlighted that intensities of electricity vary per regions and countries. Thus, numbers presented in table 6 can only be used for a relative approach of emissions. However, the total annual amount of CO_2 emitted by the case study hotel is 96 tonnes.

CHAPTER 7

7 HOTEL PERFORMANCE SIMULATIONS- MODELLING ASSUMPTIONS

Taking into account the energy distribution of the case study, this chapter aims at designing a model of the building using thermal simulations software which will approach the actual indoor thermal conditions. Furthermore, modelling assumptions are presented in detail.

7.1 TAS software

Several simulations have been carried out using the Thermal Analysis Software (TAS) developed by Environmental Design Solution Limited (EDSL). TAS software allows the comparison of alternative heating/cooling strategies, façade design for comfort, energy demand and equipment sizing (EDSL 2008).

7.2 General assumptions and simplifications

Simplifications to the building's design and assumptions concerning the periods of occupation and air-conditioning operation will be made, which will be further analyzed in this chapter.

7.2.1 Weather file

The nearest to the island of Kefalonia available weather data in a format compatible to the TAS software come from Kerkira, the Northern island in the Ionian Sea. The following chart indicates a comparison of the temperatures from the two islands (Figure 38). The trend lines of the mean monthly temperatures from the two locations converge and therefore the weather file can be representative for the location under investigation.

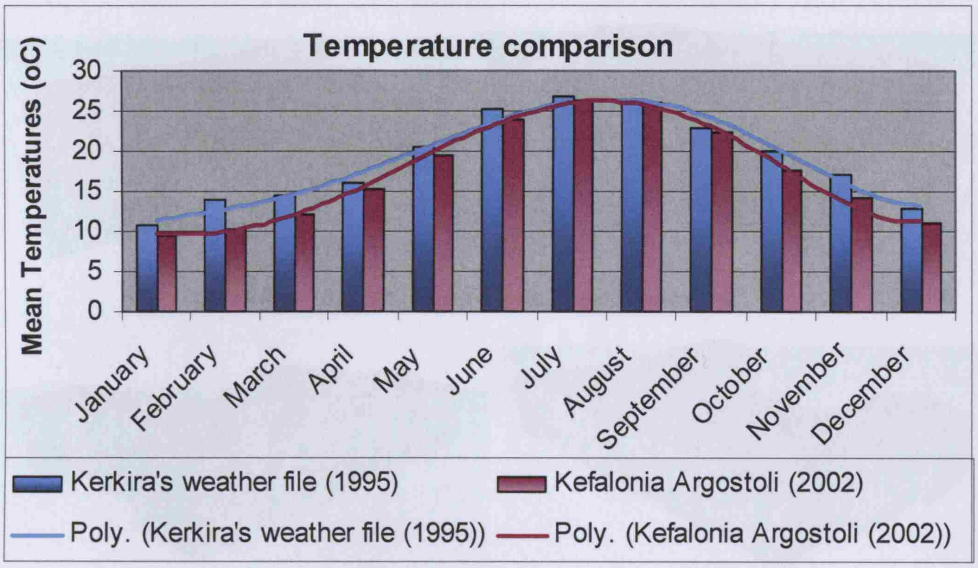


Figure 38: Temperature's comparison (Kefalonian's data, Source: HNMS 2008)

7.2.2 3-D model

Primarily, the shape of the building is modelled. The hotel constitutes of a basement, the ground floor and the first floor. Since the basement is used as a plant area, it has been assumed that it does not contribute significantly to the overall energy consumption of the hotel, therefore, and in matters of simplicity it will not be simulated in TAS.

The 3-D model of the building is illustrated below (Figures 39 & 40). Detailed information concerning the materials will be analysed in the following stage of the simulator.

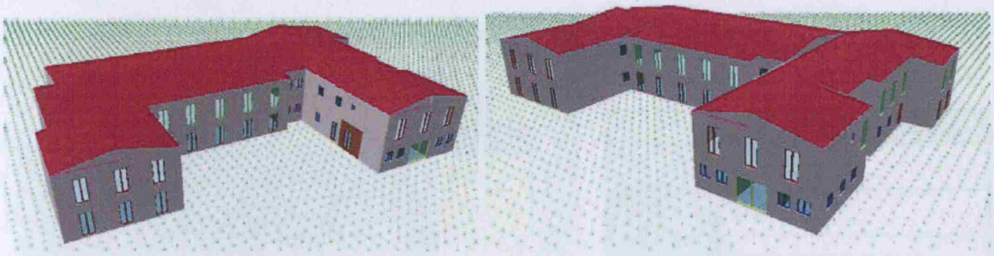


Figure 39: 3D model of the hotel, front view

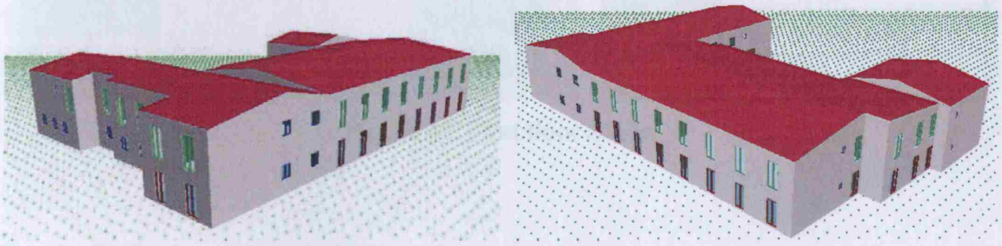


Figure 40: 3D model of the hotel, back view

7.2.3 Zoning

After completing the model and allocating the building elements, the building will need to be separated in zones according to the way the spaces are used, the temperatures as well as the internal gains obtained within them. The rooms having the same orientation are simulated as an entire zone. Therefore, 15 zones in total were created, 9 and 6 for the ground and first floor respectively (Figures 41 & 42).

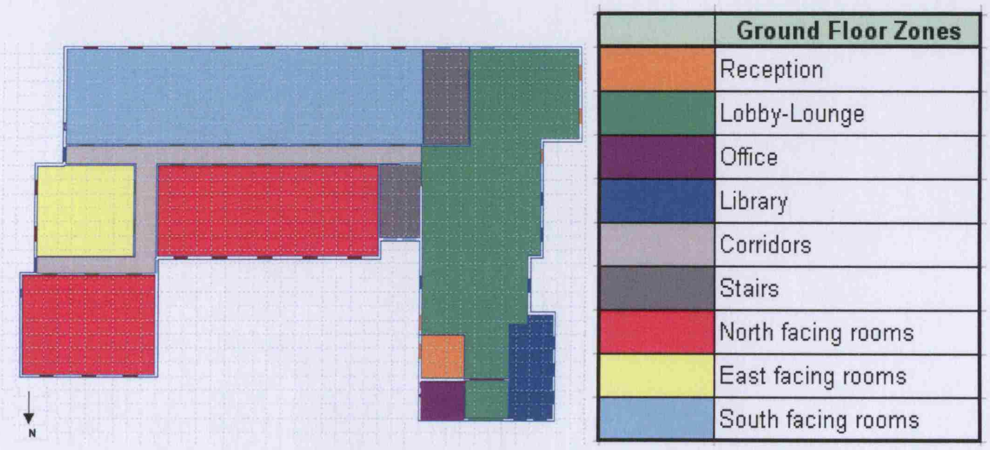


Figure 41: Ground floor zones

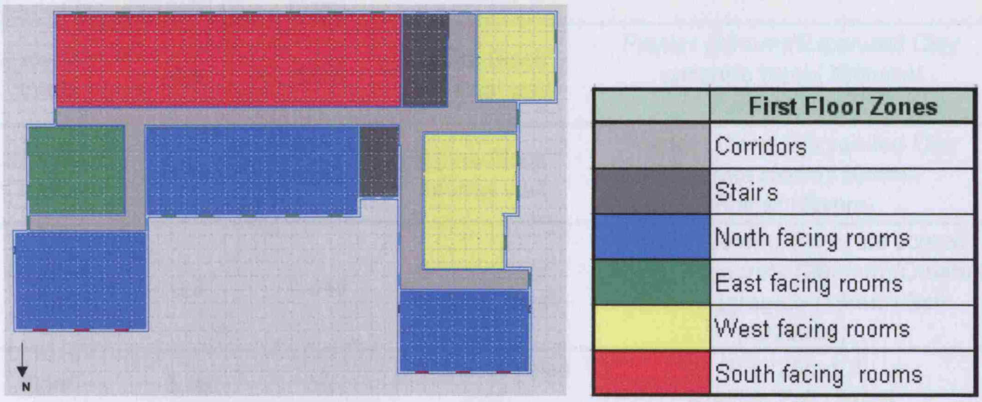


Figure 42: First floor zones

7.2.4 TAS simulator, building elements

After designing the 3-D model the next stage is the definition of the construction materials composing the building elements allocated into the model. The hotel constitutes of a lightweight construction built of a material called “Alpha-Block” that has thermal and sound insulation properties. After examining the material’s characteristics; conductivity, specific heat and density (Ytong 2008), it was found that from the given construction materials of TAS software, the most similar material to “Alpha-Block” is the “Expanded clay concrete block”. The construction materials used in the model are presents below (Table 7):

Building Elements:	U-Value (W/m^2 C)	Thickness (mm)	Description	Materials:
External Walls	0,8	250	"Alpha-Block" external wall	Plaster (25mm)/Expanded Clay concrete block(200mm)/ Plaster (25mm)
Internal Walls	0,99	200	"Alpha-Block" internal wall	Plaster (25mm)/Expanded Clay concrete block(150mm)/ Plaster (25mm)
Ground Floor	0,5	1.345	Ground floor no false floor	Marble (20mm)/Concrete screed (50mm)/Concrete (200mm)/Crushed Brick aggregate (75mm)/Soil (1000mm)
Roof	5,16	30	Uninsulated tiled roof	Tile (25mm)/ Roofing Felt (5mm)
Windows	2,97	24	Double glazed low-E windows	Kappafloat (6mm)/ Cavity (12mm)/Clear Float(6mm)

Table 7: Construction materials of the existing case

7.2.5 Schedules & Internal conditions

Internal conditions have to be determined according to coefficients for occupancy, lighting, equipment, ventilation and infiltration. Taking into account the floor area of each zone, assuming the number of occupants in each space (Table 8) and the typical rates at which heat is given by human beings according to the different states of activity (Table 9), internal gains have been estimated. The internal conditions entered into the TAS simulator are summarized in Table 10.

Zone	Floor Area (m^2)	Number of occupants	Fresh Air Ventilation Rates (l/s/p)	Space Volume (m^3)
Reception	9,5	2	10	28
Library	21,7	1	10	65
Lounge-Lobby	172,7	12	10	518
Corridors (Ground floor)	52,5	3	10	157
Rooms	20,0	2	10	60

Table 8: Number of occupants and ventilation rates for each of the main zones

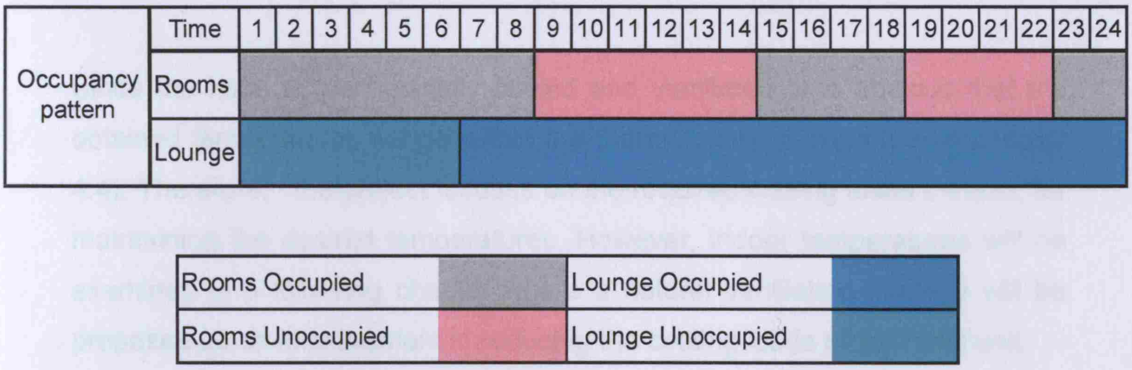
Zone	Activity	Rate of heat emission/ W			Q	Occupancy Sensible Gain (W/m^2)	Occupancy Latent Gain W/m^2)	ACH (h^-1)
		Total	Sensible	Latent				
Reception	Moderate office work	130	75	55	72	15,8	11,6	2,5
Library	Moderate office work	130	75	55	36	3,5	2,5	0,6
Lounge-Lobby	Walking Standing	145	75	70	432	5,2	4,9	0,8
Corridors (Ground floor)	Walking Standing	145	75	70	108	4,3	4,0	0,7
Rooms	Seated	115	70	45	72	7,5	4,5	1,2

Table 9: Rate of heat emission for different states of activity (Source: CIBSE, guide A 2006. p.271)

	Infiltration ACH	Ventilation ACH	Lighting gain W/m²	Occupancy Sensible Gain W/m²	Occupancy Latent Gain W/m²	Equipment Sensible Gain W/m²	Equipment Latent Gain W/m²
Rooms	0,5	1,2	10	7,5	4,5	15	0
Lounge	0,5	0,8	12	6	5	15	0
Reception	0,5	2,5	12	15	11	15	0
Corridors	0,5	0,5	10	4,2	4	10	0
Office	0,5	1,4	10	9	7	15	0
Library	0,5	0,5	10	3,5	2,5	15	0

Table 10: Internal gains

According to experienced facts, owing to the nature of occupancy of hotel buildings, customers are considered to stay within their rooms for 14 hours per pay during their holidays, whereas the lounge has been assumed to be occupied for 18 hours per day (Figure 43).



	Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupancy pattern	Rooms	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟥	🟥	🟥	🟥	🟥	🟥	⬛	⬛	⬛	⬛	🟥	🟥	🟥	🟥	⬛	⬛
	Lounge	▦	▦	▦	▦	▦	▦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

Rooms Occupied	⬛	Lounge Occupied	🟦
Rooms Unoccupied	🟥	Lounge Unoccupied	▦

Figure 43: Occupancy pattern

The room lightings have been assumed to operate for 3 hours, while the lounge, reception and corridor lightings operate 24 hours per day. Concerning the equipments' schedule of operation, it is assumed that room and lounge equipments are used for 5 hours and18 hours per day respectively.

Since the room windows are controlled according to the occupants' thermal preferences, there isn't a clear ventilation strategy of the hotel's rooms. Therefore, in order to define the demanding cooling loads of the hotel which will approach the actual loads, it has been assumed that the apertures will start to open when the rooms' temperature exceeds 21 °C, and will shut when the temperature reaches 25 °C, at which the air conditioners of the rooms will start to operate. The temperature at which the air-conditioners of the reception and lounge will operate is 26 °C.

7.3 TAS results

Since the hotel is mechanically cooled and ventilated, it is obvious that the obtained temperatures will be within the thermal comfort zone (set in chapter 4.4). Therefore, the project focuses on the required cooling loads instead, for maintaining the desired temperatures. However, indoor temperatures will be examined in a following chapter where a natural ventilation strategy will be proposed as an improvement in reducing the cooling loads of the hotel unit.

Assuming a fully occupied building the annual cooling loads from TAS are found to be 63.332 kWh (Appendix F). In order to define the actual cooling loads required for the hotel, the total loads need to be adjusted to the efficiency of the air conditioning unit.

Since the cooling system was installed in 1998 it is assumed to have a rather low efficiency. Therefore, in order to find the electric energy input to the system (delivered energy), the output (cooling load taken from the software), need to be divided by a Coefficient of Performance (COP) factor equal to 2 (Mumovic 2008) and further adjusted to the mean occupancy of the hotel.

As aforementioned, the air conditioning units in the rooms operate only when the rooms are occupied (Chapter 6.1). However, as mentioned in chapter 6.6 while comparing electricity consumption to occupation rates and external temperatures, the proportion of cooling loads to the occupancy is not linear, meaning that the A/C will operate regardless the occupancy. Therefore, it has been assumed that the mean occupancy of the hotel is 90% a percentage slightly higher than the actual occupancy which is approximately 75-80%. Therefore, the actual cooling load demand found from TAS is **28.500 kWh** (equal to 20,4 kWh/m^2) per year ((63.332/2)*0,9 kWh).

7.4 How representative is the TAS model?

The aim of the modelling approach of this project is not to "regenerate the actual" mechanism of the thermal analysis of the hotel, but to create a model which is equivalent and represents the actual conditions. Therefore, some of the components are not identically integrated.

In order to ascertain if the designed model in TAS represents the reality, the results from the internal temperatures coming from the simulations are compared to the ones monitored by sensors placed in the hotel's reception (HOBO 2008). The period of monitoring lasted for 41 days (15 May to 24 June 2008) and the results from the comparison are presented in figure 44.

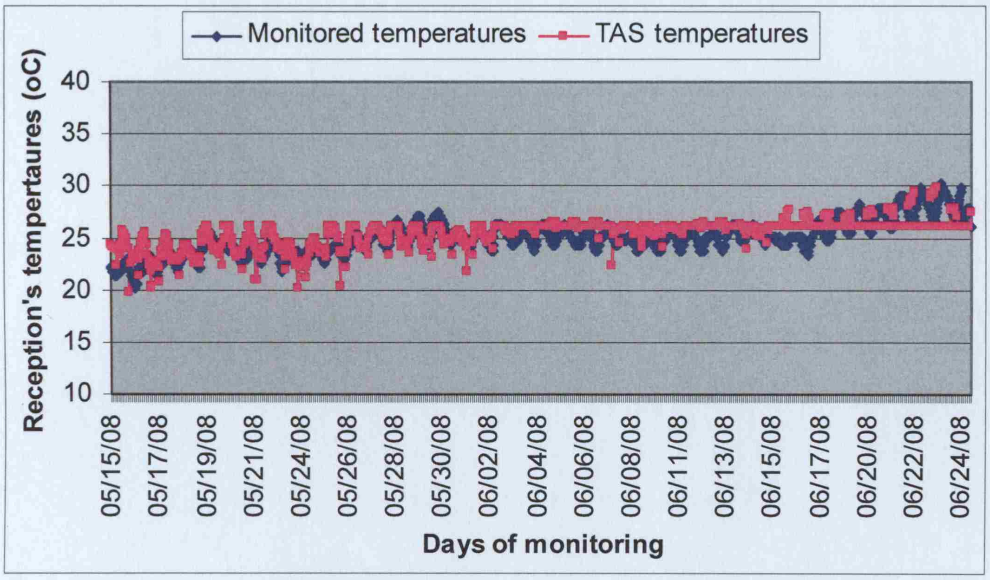


Figure 44: Reception's temperatures from simulation results and from monitoring

Figure 44 indicates that the resulting temperatures from TAS follow the trend of the actual monitored temperatures. In order to have an arithmetical representation of the results, the dispersion has been estimated and is equal to 1,9 therefore, the standard deviation equals 1,3.

Furthermore, by comparing the cooling loads estimated in chapter 6.7 (28.000 kWh) to the ones found from TAS 28.500 kWh, it is obvious that the differences between them are inconsiderable.

Thus, it can be concluded that the designed model is equivalent to the actual conditions. Therefore, energy conservation scenarios which will be further proposed will not only have a qualitative but also quantitative character.

7.5 Identify energy demands

The following diagram illustrates the effect of the orientation of the rooms and their floor height to the cooling demand (Figure 45). As it can be seen, the amount of cooling loads of the west facing rooms for the ground and first floor, are by far the highest loads of the hotel. Furthermore, the demanding cooling loads of the first floor are approximately 6 kWh/m^2 higher than the loads of the ground floor.

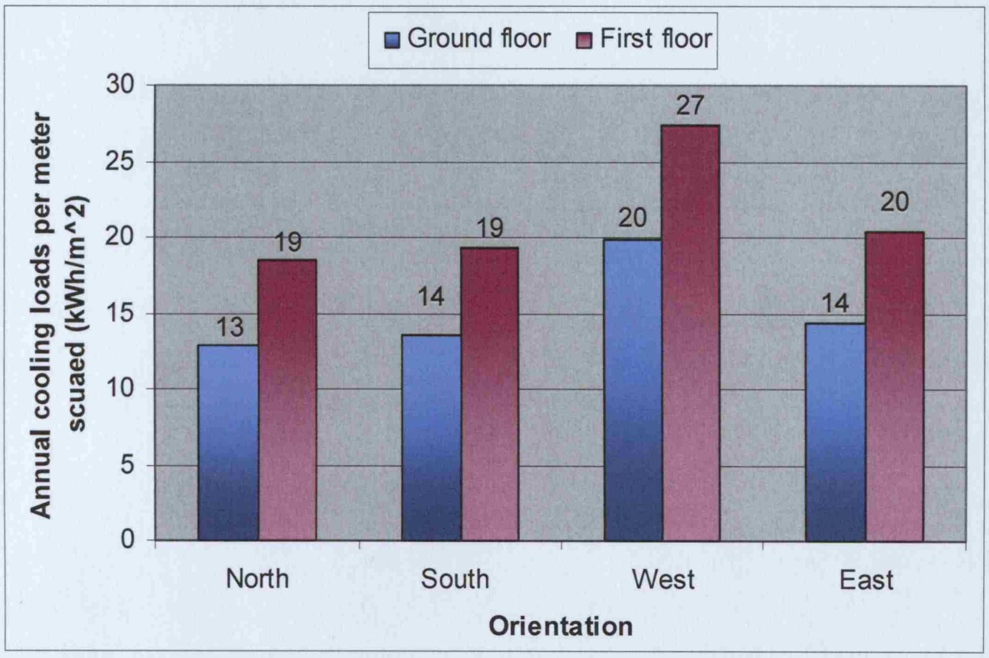


Figure 45: Cooling loads in terms of orientation and floor

From the above diagram it can be concluded that, the building's orientation plays a significant role on its energy consumption.

CHAPTER 8

8 HOTEL PERFORMANCE SIMULATIONS- RETROFITTING CASE SCENARIOS

8.1 Energy conservation measures:

In this chapter energy conservation techniques will be applied and evaluated to the hotel through a series of simulations using TAS. Therefore, the effects of solar control, upgrading the building's fabric and glazing, and the enhancement of natural ventilation in reducing energy consumption will be examined. The main objective is to recommend techniques aiming to reduce the cooling loads of the case study.

8.1.1 Shading

Glazing facades contribute significantly to the overall energy consumption of a building since they allow solar radiation and heat transmission penetrate into the conditioned space, leading to high air conditioning loads. A way of reducing the amount of energy used for cooling the building is by controlling the direct solar heat gains from the windows through solar protective devices such as overhangs louvers or blinds (CIBSE TM37, 2006, p.1).

The application of overhangs has been simulated in TAS. Overhangs with different slopes towards the windows extending downwards from the top edge have been applied to all the glazing apertures of the hotel. Their characteristics followed by the reduction in the cooling loads are summarised in the tables 11 and 12.

Building Elements	Element's dimentions		Overhang's dimentions	
	Height (m)	Width (m)	Depth (m)	Width (m)
Windows	1	0,9	0,5	1,2
Room glazing doors	2,1	1	1,1	1,3
Entrance glazing door	2,1	2,5	1,5	2,8

Table 11: Window's and overhang's characteristics

Shading	Overhang's slope towards the window (Deg.)	Annual cooling loads (kWh)	Annual cooling loads per meter squared (kWh)	Percentage of cooling loads reduction from existing case (%)
Existing case	Without overhangs	28.499	20,4	-
1st Option	90	26.658	19,0	6,5
2nd Option	80	26.394	18,9	7,3
3rd Option	70	25.874	18,5	9,2
4th Option	60	25.377	18,1	10,9
5th Option	50	25.139	18,0	11,7

Table 12: Effect of overhang's slope in reducing cooling loads

Table 12 indicates that the smaller the angle of the overhang towards the window, the less required cooling loads. However, shading devices should be designed in respect to the available daylight and the occupant's visual comfort. Therefore, an opaque overhang with a slope of less than 60 Deg. will block natural daylight and will result in excessive use of artificial light. Thus, the optimum solution for the hotel is the overhang with a tilt of 60 Deg. towards the windows leading to 10% reductions in the cooling loads from the base case scenario.

8.1.2 Blinds

In a further simulation, two alternative scenarios for blinds will be proposed. The first concerns light internal blinds and the second scenario regards shutters simulated as dark external blinds. Table 13 indicates that external dark shutters cause a reduction by approximately 10% whereas the light internal blinds decrease the cooling loads by 5% compared to the base case.

At this point it should be noted that schedules have been applied to the both of the blinds. The blinds will be shut during the day (9 a.m. to 10 p.m.). However, in order to allow daylight penetration and avoid excessive artificial lighting while the rooms will be occupied (2 p.m. to 6 p.m.), shutters are set to open (Chapter 7.2.5, figure 43 for occupancy schedules).

Blinds	**Description**	**Annual cooling loads (kWh)**	**Annual cooling loads per meter squared (kWh/m^2)**	**Percentage of cooling loads reduction from existing case (%)**
Existing case	Without blinds	28.499	20,4	-
1st Option	Light internal blinds	27.136	19,4	4,8
2nd Option	Dark external shutters	25.700	18,4	9,8

Table 13: Effect of blinds in reducing cooling loads

Since dark shutters already exist in the current construction and they cause a great reduction in the cooling loads from the existing case, they have been selected as an optimum solution.

8.1.3 High performance glazing

Glazing windows contribute significantly to the energy consumption of a building. Therefore, several glazing with spectrally selective properties and coatings according to the cool glazing configuration (Appendix G) will be examined to ascertain their effect on cooling loads for the case study (Table 14).

Glazing	U-Value	Description	Materials	Annual cooling loads (kWh)	Annual cooling loads per meter squared (kWh/m^2)	Percentage of cooling loads reduction from existing case (%)
Existing case	2,97	Current simple double glazing	Clear float (4mm)/ air (hor. flow)(10mm)/ clear float (4mm)	28.499	20,4	-
1st Option	1,80	Low-E double glazing	Kappafloat (6mm)/ air (hor. flow)(12mm)/ clear float (6mm)	27.761	19,8	2,3
2nd Option	1,54	Low-E, coated double glazing	Clear glass (4mm)/ air (hor. flow)(6mm)/ Low-E glass (6mm)	27.437	19,6	3,7
3rd Option	1,80	Antisun, green, Low-E, double glazing	Kappafloat (6mm)/ air (hor. flow)(12mm)/ antisun (Bronze) (6mm)	26.009	18,6	8,7
4th Option	2,30	Sun cool, double glazing, silver coating	Optifloat clear (6mm)/ air (hor. flow)(12mm)/ suncool classic silver (6mm)	24.040	17,2	15,6

Table 14: Effect of different glazing coatings in reducing cooling loads

According to the findings from the simulations it was found that the sun cool glazing with silver coating presents the optimum performance by far comparing to other examined solutions, by reducing the cooling loads by 15, 6% from the existing case.

8.1.4 Roof Insulation

In order to decrease the flow of heat into the building when the external temperatures are higher than the internal ones, it is essential to consider the thermal insulation of the structure. Well insulated structure in combination with a right control of solar gains and ventilation can lead to a cooler building during the summer (McMullan 2007, p.14). Therefore the effect of adding insulation to the roof, a major source of radiant heat gain to the overall energy performance of the building will be examined. Several thicknesses of insulation have been tested. The proposed roof construction characteristics are summarized in table 15.

Roof	Width (mm)	U-Value	Materials	Annual Cooling loads (kWh)	Annual Cooling loads per meter squared (kWh/m^2)	Percentage of cooling loads reduction from existing case (%)
Existing case	30	5,16	Roofing Felt (5mm)/ tile (25mm)/	28.499	20,4	-
1st Option	175	0,33	Plasterboard(25mm)/ glass fibre (100mm)/ cavity (20mm)/ roofing felt(5mm)/ tile (25mm)	26.219	18,7	8
2nd Option	275	0,18	Plasterboard(25mm)/ glass fibre (200mm)/ cavity (20mm)/ roofing felt(5mm)/ tile (25mm)	25.909	18,5	9
3rd Option	375	0,12	Plasterboard(25mm)/ glass fibre (300mm)/ cavity (20mm)/ roofing felt(5mm)/ tile (25mm)	25.775	18,4	9,6

Table 15: Effect of roof's insulation thickness in reducing cooling loads

Table 15 indicates that the higher the levels of insulation the lower are the U-values, a fact meaning that the thermal transmittance is being reduced and therefore the cooling loads are being decreased. The thickness of 200mm of roof insulation seems to give satisfactory reductions.

8.1.5 External wall Insulation

A further proposal concerns the addition of insulation to the external walls. The current and proposed building elements followed by their characteristics are presented in the following table 16.

External Walls	Width (mm)	U-Value (W/ m^2C)	Description	Materials	Annual cooling loads (kWh)	Annual cooling loads per meter squared (kWh/m^2)	Percentage of cooling loads increase from existing case (%)
Existing case	250	0,80	"Alpha-Block" uninsulated external wall	Plaster (25mm)/ exp.clay concrete block(200mm)/ plaster (25mm)	28.499	20,4	-
Proposed option	430	0,22	"Alpha-Block" insulated external wall	Plaster (25mm)/ exp.clay concrete block(200mm)/ exp.polysterene (100mm)/ air (hor.flow)(50mm)/ plasterboard (30mm)/ plaster (25mm)	28.788	20,6	1

Table 16: Effect of wall insulation in the cooling loads

Surprisingly the addition of insulation slightly increases the cooling loads by 1%. Explanatory since the existing material composing the external walls ("Alpha-block") has thermal insulation properties, the further addition of insulation could exceed the recommended values of building codes and it is possible to result in increasing slightly the cooling loads (Santamouris et al 1996).

8.1.6 Mixed-mode ventilation

As described in chapter 5.3, the case study hotel is located at a rural area where by noise and pollution levels are not considered as an issue, and external climatic conditions do not perform extreme temperatures during the summer. Furthermore, the building comprises of narrow plan rooms with single openings, therefore, natural ventilation is possible to be introduced supplemented by mechanical ventilation when outdoor conditions are not favourable. The effect of a mixed mode scenario to the overall energy conservation of the building will be examined.

At a first stage night ventilation is proposed. The concept of night ventilation "utilises the lower external nigh-time temperatures to pre-cool the building's structure and thereby reduce the mean radiant temperature of the space which enhances the occupant's perception of thermal comfort throughout the following day" (CIBSE AM10, 2005. p. 19).

However, in order to avoid overcooling the space, apertures are set to close when the internal temperature drops below certain temperature defined as the lower boundary of the thermal comfort zone (determined in chapter 4). The ventilation strategy for each of the zones of the hotel is described bellow.

Rooms:

During the day apertures will be kept closed. The four hours of the day during which rooms will be occupied (Occupancy schedule defined in chapter 7.2.5), air conditioning is set to operate at 25 ^{0}C. Night ventilation will be introduced from 10 p.m. to 8 a.m. during which windows will be open. However, when the internal temperature drops bellow 21 ^{0}C either rises above 27 ^{0}C, windows will close.

Lounge- Reception- Corridors:

During the day while the common areas of the corridors and lounge will be occupied, apertures will be closed and mechanical cooling will operate at 26 ^{0}C. In order to remove heat stored in the building's fabric during the day, night ventilation will be introduced from 1 a.m. to 8 a.m. so as to enhance the following's day temperature to start from lower limits.

After a series of simulations it was found that night ventilation reduces significantly the amount of cooling loads by 34,6% from the base case (Table 17).

	Annual Cooling Loads (kWh)	**Annual Cooling Loads per meter squared (kWh/m^2)**	**Percentage of cooling loads reduction from existing case(%)**
Existing Case	28.499	20,4	-
Night Ventilation	18.637	13,3	34,6

Table 17: Effect of night ventilation in reducing cooling loads

At this point it should be noted that the effectiveness of natural ventilation techniques, strongly depends of the space's layout. As aforementioned the main plan of the hotel is narrow plan in which the room's dimensions perform the conditions of single sided ventilation strategy with a single opening (W=<2H) (CIBSE AM10, 2005. p. 15) (Figure 46).

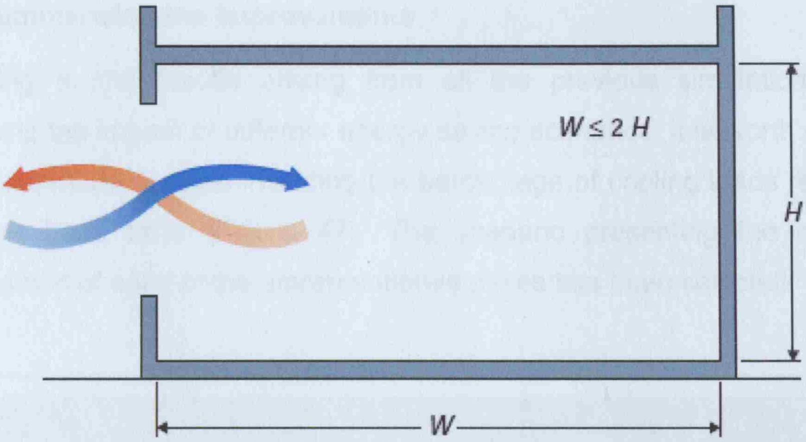


Figure 46: Single sided ventilation in the hotel's rooms where W=5,5 m and H=6 m (Source: CIBSE AM10, 2005, fig 2.18, p.15)

Last but not least, it is important to note that the enforcement of night ventilation strategy in the hotel rooms requires the cooperation of the room occupants especially in the case that apertures will be automatically controlled (Santamouris et at 1996).

8.2 Summarizing the improvements

According to the results arising from all the previous simulations while examining the impact of different energy saving scenarios, it is worth creating a final summarising table including the percentage of cooling loads reduction from the base case (Figure 47). The scenario presenting the optimum performance of each of the aforementioned cases has been selected.

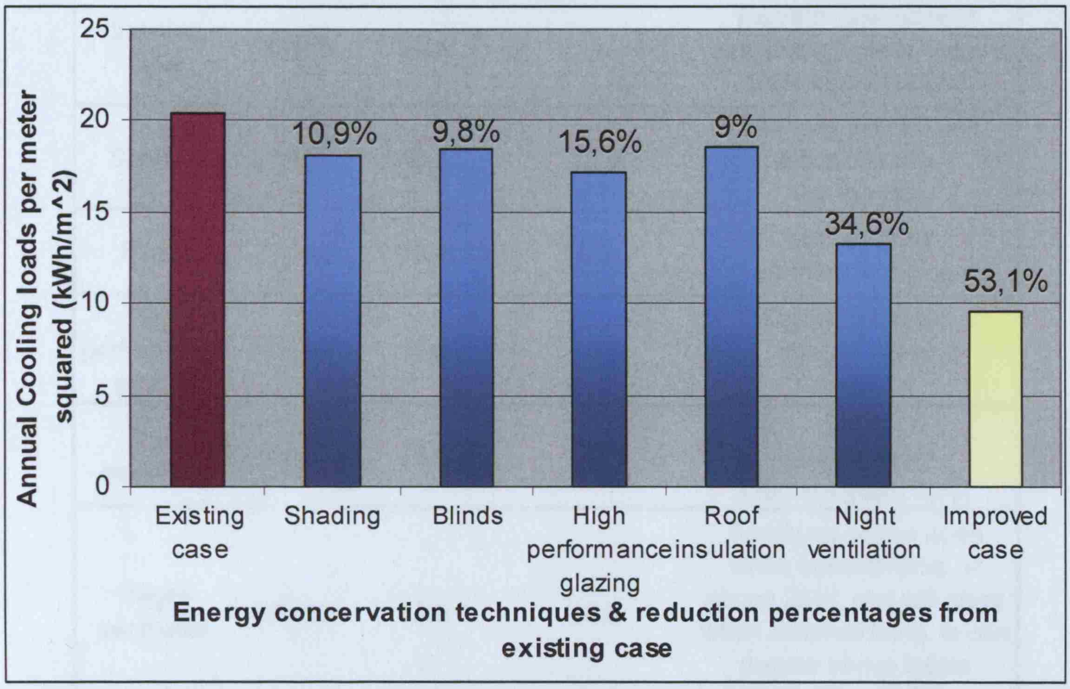


Figure 47: Annual cooling loads for several energy saving techniques and their reduction percentage from the base case

As it can bee seen from the above diagram the best performance scenario presents night ventilation where by cooling loads are being decreased by approximately 35%. High performance glazing with spectrally selective properties and coatings decrease the total cooling loads by about 16%. Cooling loads can be further reduced by 10% by the application of shading, roof insulation and external dark blinds.

The following table summarizes the results presented in figure 47 followed by their characteristics (Table 18).

Cases	Annual cooling loads (kWh)	Annual cooling loads per meter squared (kWh/m^2)	Percentage of cooling loads reduction from existing case (%)	Description
Existing case	28.499	20,4	-	Current case without any energy concervation techniques applied
Shading	25.377	18,1	10,9	Overhang with 60 deg. slope towards the window
Blinds	25.700	18,4	9,8	Dark external shutters in rooms
High performance glazing	24.040	17,2	15,6	Sun-cool double glazing, silver coated
Roof insulation	25.909	18,5	9	Tiled, insulated roof (200mm glass fibre)
Night ventilation	18.637	13,3	34,6	Apertures will be open when internal temp. is above 22oC and will close when external temp. is one degree above inside from 10pm to 8am
Improved case	13.352	10	53,1	All improvements applied

Table 18: Summary table of optimum performance energy saving techniques

The application of all of the aforementioned improvements to the hotel, cause a significant reduction in the cooling loads by 53.1 % from the existing base case.

As mentioned in chapter 6.7 (Figure 37) the cooling loads represent 21% of the total energy consumption of the case study. Therefore their reduction by half corresponds to a decrease by **10%** of the total energy consumption.

Furthermore, it is evident that the proposed energy conservation techniques, do not act augmentative. Explanatory, the improved model in which all of the above methods will by applied, will not lead to reductions in the cooling loads equal to the sum of each individual reduction. This is due to the fact that the effects of some of the proposed energy saving techniques overlap some others. For instance, the effect of introducing high performance glazing would not take place if at the same time dark external shutters were used. Therefore, the selection of the best combination for implementation will consider the interaction of the aforementioned methods, and in a further step, their cost.

8.3 Arising issues

According to the recapitulating table with the energy conservation techniques (Table 18), someone could conclude that the adoption with night ventilation strategy could be by far the most appropriate solution, achieving the greatest energy savings. However, the temperatures obtained within the thermal comfort zone with the implication of the aforementioned cases, should be considered as well. According to the adaptive approach of thermal comfort mentioned in chapter 4.4, the thermal comfort limits sticking to an acceptability of 80%, are 22 ^{0}C to 29 ^{0}C. The percentage of temperatures of the first floor out of the thermal comfort zone only by the operation of night ventilation is above 10% (Figure 48). Nevertheless, the installation of all of the aforementioned techniques decreases that percentage by half.

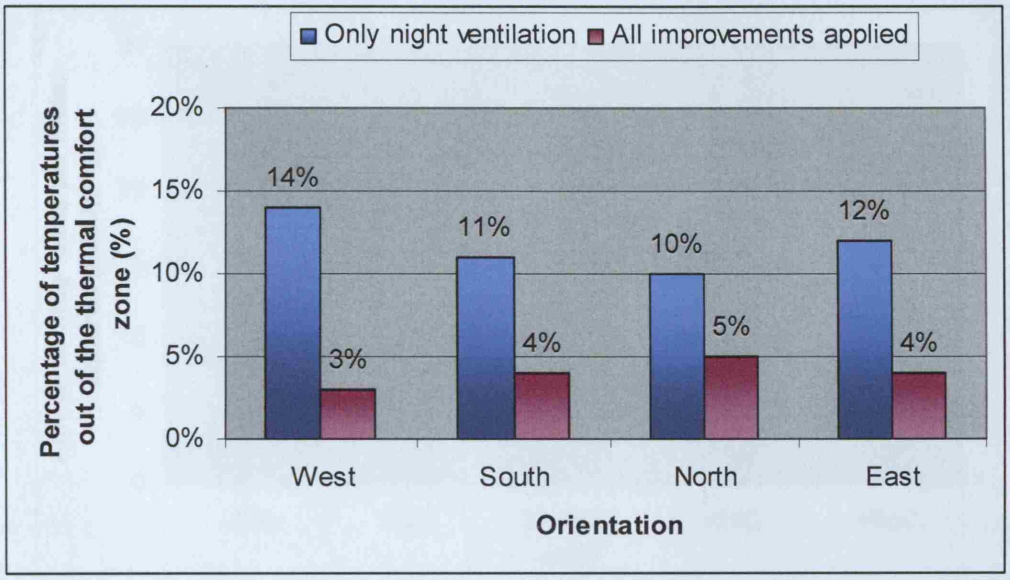


Figure 48: Percentage of 24-hour temperatures outside the thermal comfort zone for the rooms of the first floor

Therefore, it is preferable to consider night ventilation in combination to the aforementioned energy saving techniques such as shading or roof insulation, since it leads to better results by increasing the amount of temperatures within the thermal comfort zone. Concerning the ground floor, it interacts rather well only with the adoption of night ventilation since the obtaining temperatures within the thermal comfort zone exceed 94%.

8.4 Further energy saving techniques

This paragraph will develop further techniques in reducing the overall energy consumption of the case study hotel.

8.4.1 Thermostat setting

Figure 49 indicates the way energy consumption is associated to the temperatures the thermostats are set within the rooms. As it can be seen, the lower the temperature sets in the thermostats, the higher the energy consumption will be for cooling. Each one degree Celsius increase in thermostat setting leads to a 10% reduction in cooling loads (Appendix H).

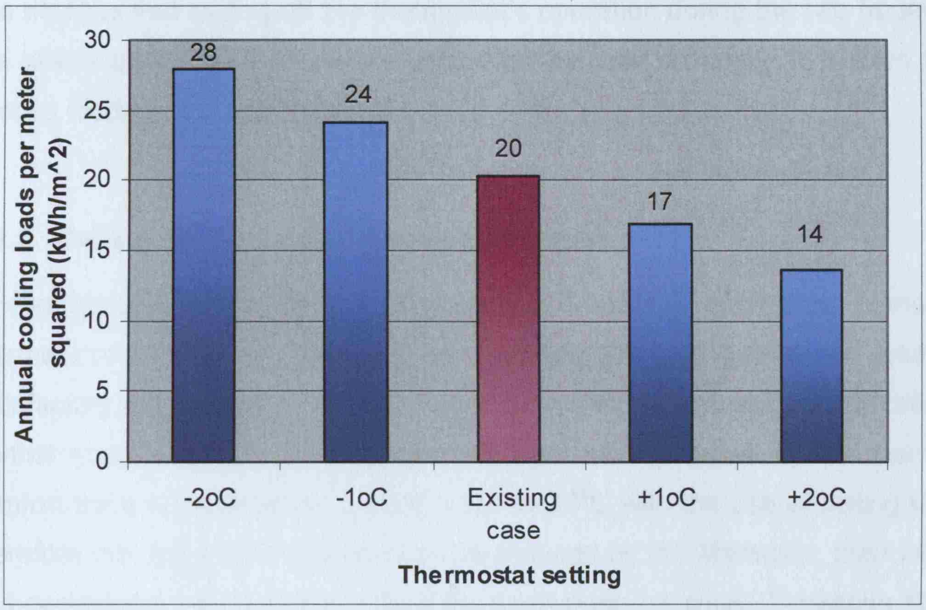


Figure 49: Cooling loads in correlation to the temperature set in the thermostats

Furthermore, the effect of reducing the thermostat's operation by two hours during a day has been examined. Several hours during the day have been tested regarding their effect in reducing the cooling loads (Figure 50).

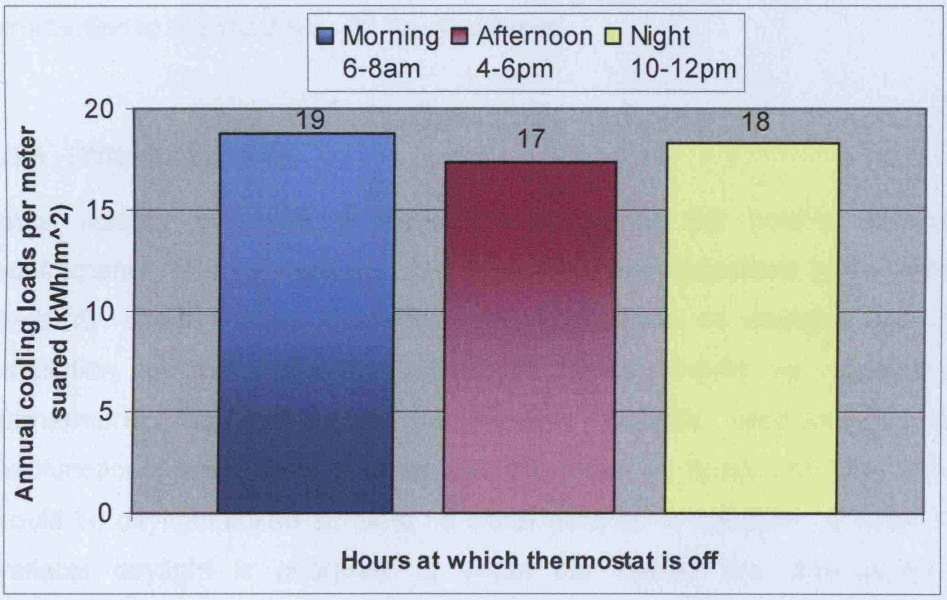


Figure 50: Effect of cutting off the thermostat's operation at several schedules in reducing cooling loads

It is obvious that cutting off the thermostat's operation during the two hours of the afternoon cause the greatest reduction by approximately 15% from the cooling loads of the existing case.

8.4.2 Ceiling fans- passive cooling techniques

Taking into account the factors mentioned in chapter 4 which affect human's thermal comfort, the circulation of air produced by ceiling fans can lead to satisfactory indoor thermal conditions by minimizing temperature stratification. Furthermore, according to the adaptive approach (chapter 4) the thermal comfort zone is expected to extend close to 30°C with the use of ceiling fans therefore the demand for cooling can be reduced by far. Moreover, their initial and operational cost is low and their pay back period is small (Scheatzle 1989 cited in Santamouris 1996).

Furthermore, passive cooling techniques such as evaporative cooling from the sea, swimming pools either fountains can increase humidity levels and by reducing air temperatures can lead to decreasing cooling loads therefore their introduction to the hotel should be considered.

8.4.3 Efficient lighting

Since lighting accounts a large percentage of the hotel's electricity requirements, its conservation can lead to significant reductions in the overall electricity consumption. Therefore, the exploitation of daylight and the installation of high efficacy fluorescent lamps should be considered. Furthermore, the introduction of effective controls especially to the multifunctional areas where lights are operating 24 hours per day, which should be daylight linked so as to be either dimmed or switched off when the available daylight is adequate or when the spaces are unoccupied is essential. To sum up, modest levels of lighting gains, can lead to reductions of cooling loads (CIBCE, TM37 2006, p.17).

8.4.4 Energy efficient appliances- Maintenance- Boiler upgrading

According to the energy distribution of the case study, a large proportion of the energy is being consumed by electric appliances. The use of low power rated and high efficiency equipment can lead to reductions in the electricity loads. Furthermore, most machines of plant are designed to operate at maximum load. However, in reality since they are linked with the occupancy rates, they operate at part load. Therefore, the operational efficiency is much lower than the designed one. Thus, it should be ensured that plant are not over-sized and even down grade where appropriate (BRECSU 1997, p. 153).

Furthermore, proper maintenance of all the systems is necessary and can help them operate more efficiently and therefore reduce excessive energy consumption.

Furthermore, the replacement of the existing conventional boiler to a more efficient condensing boiler, recovering waste heat from the hot flue gases should be considered. However, condensing boilers have higher capital costs although they have short pay back periods (De Saulles 2000, p.13).

8.5 Cost analysis

The success of the implementation of the aforementioned techniques will be based in the best combination of energy conservation and costs. In this chapter a rough estimation of the costs of the aforementioned improvements will be developed according to the pricing of the Greek market. The following table summarises the total costs of some of the recommended energy saving techniques (Appendix I).

	Description	Min cost including installation& VAT (€)	Maxcost including installation& VAT (€)	Average cost including installation& VAT (€)
Shading- Overhang	Wooden structure with tiles	3.580	7.160	5.370
High performance glazing	Sun-cool silver coated double glazing	12.900	19.350	16.125
Roof Insulation	Fiber glass roof insulation	3.000	5.400	4.200
Night ventilation	Reminding labels to the occupants to leave the windows open during the night	100	150	125
Dark Shutters	Reminding labels to the occupants to shut the already existing shutters when leaving the rooms	100	150	125

Table 19: Costs of upgrading the hotels energy performance (Source: Stegokataskevastiki 2008, Pilkington Greece 2008, Protectivo 2008)

The adoption of night ventilation and the utilization of existing dark shutters correspond to minimum costs, possibly linked to the notification of occupants for a manual operation of the apertures either their adjustment to a system which will automatically control their opening and closing. It is obvious that a further inexpensive solution initially concerns the addition of roof insulation and as a further step the installation of overhangs. High performance glazing has the highest initial cost of the examined energy efficient techniques.

CHAPTER 9

9 TECHNICAL FEASIBILITY AND ECONOMIC VIABILITY OF A GRID-CONNECTED PV INSTALLATION IN THE CASE STUDY HOTEL:

This chapter will assess the techno-economic feasibility of the installation of a grid-connected PV system in the case study hotel. PV's output, economical and technological characteristics will be found using a renewable- energy technologies software.

9.1 Photovoltaic technology

Photovoltaic's technology convert solar radiation into electricity without producing any greenhouse gases. The development of the photovoltaic industry and tourism was significant the last decade. Photovoltaic installations are linked to ecological tourism which refers to the reduction of power generated by fossil fuels and it is linked to rational electricity consumption (Bakos and Soursos 2002) (Appendix J).

9.2 Description of PV installation

A grid connected system is proposed to be installed in the pitched roof of the hotel. Grid connected systems are connected to the PPC of Greece and when surplus electricity is produced, it can be supplied to the public power supply. During the night and in cloudy days power from the grid can be supplied to the system.

The available area of the pitched roof facing south is 225 m^2. For high efficiency requirements, the proposed PV is a mono-silicon panel with an efficiency of 14,2 % and frame area of 1,30 m^2. The system consists of 173 panels of type NT-185U1 with a PV module rating of 185 W each, nominal PV array power of 32,01 kWp and six inverters converting DC to AC electricity of nominal power of 5 kWp each. Additionally, the PV system will include a unit for a general control of the system's operation (Figure 51).

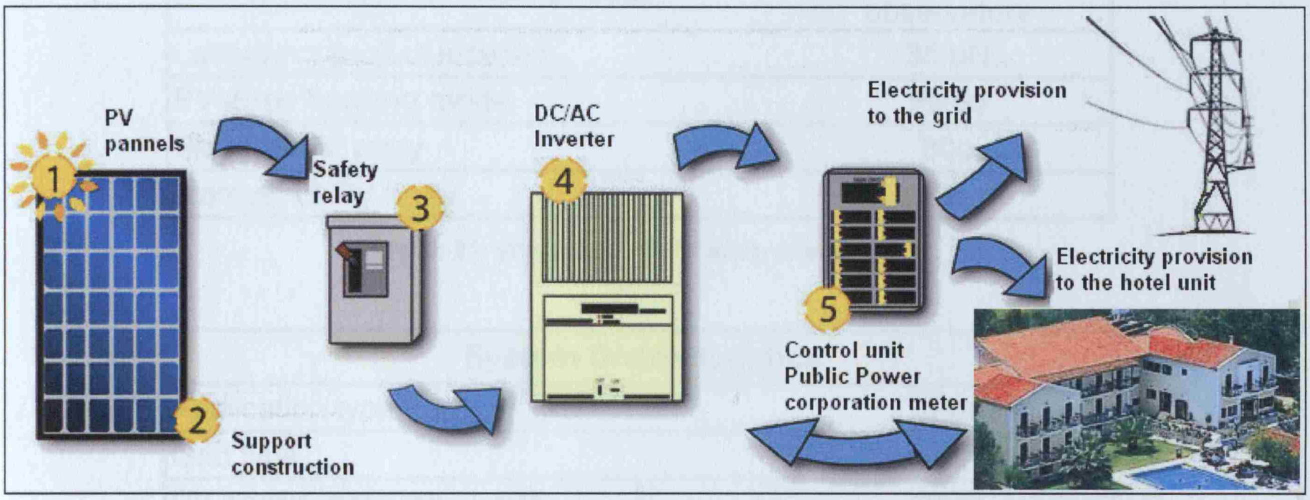


Figure 51: Main components of a grid connected PV installation (Source: Solar systems 2008)

9.3 Economic assessment- Electric demand- Capital cost- Output results

The PV's system output and techno-economic assessment was calculated by the RETScreen International's Clean Energy Project Analysis software (RETScreen 2000). The information that have been insert and calculated to and from the software, are summarized in the following tables (Tables 20, 21& 22) (Appendix L).

Site Conditions	
Project name	Hotel "Sami Beach"
Project location	Sami, Kefalonia
Nearest location for weather data	Athens observatory
Latitude of project location	38 oN
Annual solar radiation (tilted surface)	1,72 MWh/m^2
Annual solar radiation (Horizontal)	1,58 MWh/m^2
Annual average temperature	17,7 oC

Table 20: Site conditions

Site latitude and PV array orienation	
Nearest location for weather data	Athinai (Athens) observatory
Latitude of project location	35 oN
PV array tracking mode	Fixed
Slope of PV array	30o
Azimuth of PV array	0o

Table 21: Site latitude & PV array orientation

System Characteristics	
Application type	On-grid
Grid type	Central-grid
PV energy absorption rate	100%
PV module type	mono-Si
Nominal PV module efficiency	14,20%
Nominal Operating Cell temperature	45 oC
PV temperature coefficient	0,40%/oC
Miscellaneous PV array losses	5%
Nominal PV array power	32,01 kWp
PV array area	225,4 m^2
Average inverter efficiency	90%
Suggested inverter (DC to AC) capacity	28,8 kW (AC)
Inverter capacity	5 kW (AC)
Miscellaneous power conditioning losses	0%

Table 22: System characteristics

Taking into account the aforementioned data, the software calculates the amount of electrical energy delivered by the photovoltaic array (Table 23):

Annual Energy Production (12 months analysed)	
Specific yield	196,2 kWh/m^2
Overall PV system efficiency	11,40%
PV system capacity factor	15,80%
Renewable energy collected	49,13 MWh
Renewable energy delivered	44.220 kWh
Excess RE available	0 MWh

Table 23: Output results of the proposed photovoltaic system

As mentioned in the chapter defining the electricity demands (Chapter 6.7) of the hotel, the annual (six-month operation) electricity demands are approximately 100.400 kWh. The annual renewable energy delivered has been found to be 44.220 kWh. Therefore, the PV installation can only cover the hotel's electricity demands by 44%. The remaining demand can be covered by the grid.

9.4 Greenhouse gas emission reduction analysis

At this point the baseline electricity system of Greece is defined in order to calculate greenhouse gas emission reduction. The generation of electricity in Greece by fuel used, is presented in table 24 (Appendix K).

Base case electricity system	
Coal & Lignite	66%
Petroleum products	16%
Natural % delivered gases	12%
Hydro & wind	6%

Table 24: Electricity generation by fuel used in Greece (Source: NS 2001)

Table 25 summarizes the reductions in greenhouse gas emissions:

GHG Emission Reduction Summary			
Base case GHG emission factor (tco2/MWh)	Proposed case GHG emission factor (tco2/MWh)	End-use annual energy delivered (MWh)	Annual GHG emission reduction (tCO2/yr)
0,91	0,00	42,45	38,41

Table 25: GHG emissions reduction

9.4.1 Payback times

In order to measure the required time to recover the investment, the calculation of the payback time is essential. The simple economic payback period is the result of the division of the capital cost to the annual savings and is given by the following formula:

$$P = \frac{C}{S}$$

The initial costs include costs for the installation and the development of the proposed project (Table 26).

Initial costs		
Feasibility study	2,8%	10.000,0 €
Development	4,2%	15.000,0 €
Engineering	15,4%	55.000,0 €
Energy equipment	56,6%	184.058,0 €
Balance of equipment	21,2%	75.557,0 €
Miscallenous	4,9%	17.390,0 €
Total Initial costs	**100,0%**	**357.005,0 €**

Table 26: Initial costs (Values copied from RETScreen software)

The annual savings are the savings acquired through the implementation of the project. In order to reduce the pay bay-back time of the installation for this certain on- grid installation it has been assumed that the energy produced by the PVs will be sold to the grid with the feed-in tariff of 0,45 €/kWh (HELAPCO 2008) and will be bought back from the grid by 0,07 €/kWh (PPC 2008). Therefore, for each kWh sold to the grid, 0,38 € can be saved. The total annual savings are presented in table 25.

Annual savings or income	
Energy saving income	19.899,0 €
RE production credit income	663,0 €
Total annual savings	**20.562,0 €**

Table 27: Annual Savings

Using the aforementioned formula, the simple pay back period, time for the investment to be recovered, has found to be **20,5** years.

According to studies by the PPC of Greece, the electrical energy demand increases dramatically in such way that local dilute grids will not be able to support their needs. The PPC is called to address that weakness and meet the electricity demands especially during the tourist season which are appearing to be increased (Bakos and Soursos 2001). Therefore, even though the initial cost of PV's would sound enormous, the value of it is that it can save the government of building another power station in order to meet the increasing electricity demands.

CHAPTER 10

10 FURTHER DISCUSSION

To summarize, in order to present clearly the findings from this study, it is essential to demonstrate energy savings in correlation to the CO_2 reductions and the corresponding approximate costs of the proposed upgrading (Table 28).

Cases	Average cost of improvement (€)	Annual cooling loads (kWh)	Annual cooling loads per meter squared (kWh/m^2)	Total tonnes of CO2 produced (tn)	Total tonnes of CO2 removed (tn)	Percentage of CO2 reduction from existing case (%)	Life-time of energy efficiency measure (years)	Cost per tonne CO2 removed for the life time of improv. (€/(tn*ys)	Total tonnes of CO2 removed for the improvement's life-time (tn*ys)
Existing case	-	28.499	20	25	-		-	-	
Shading-Overhangs	5.370	25.377	18	22,2	2,8	11,2	25	77	70
High perform. glazing	16.125	24.040	17	21,1	3,9	15,6	25	165	98
Roof insulation	4.200	25.909	19	22,7	2,3	9,2	25	73	58
Night ventilation*	125	18.637	13	16,3	8,6	34,8	30	0	258
Dark Shutters	125	25.700	18	22,5	2,5	10,0	25	2	63
Improved case (1) (All energy efficiency measures integrated)	25.820	13.352	10	11,7	13,3	53,2	26,3	74	349
* Note that windows are excluded									

Table 28: Energy savings in cooling loads in correlation to the costs and the CO_2 removed from upgrading the fabric from the existing case

Some of the arising conclusions from the table 28 are the following:

- Shading and roof insulation constitute techniques with rather low cost of installation and satisfactory reductions in energy consumption and CO_2 emissions from the existing case. Thus, their integration should be initially considered since it does not scarify either the thermal or visual comfort of occupants.
- By utilizing the already existing dark shutters for solar control during the day hours while the rooms will be unoccupied, rather sensible reductions in CO_2 and energy may be achieved. At the same the requiring costs are the minimum.
- Night ventilation leads to significant reductions in CO_2 emissions and energy consumption through the decrease of cooling loads at a very low cost. However, the relation of hotel occupants and night ventilation needs to be considered. The implementation of night ventilation requires customers' condescension. Therefore, it is critical whether all of the occupants will agree towards that technique, taking into account arising security issues and possible low temperatures.
- Since the positive effects in energy conservation of upgrading the glazing will not take place if at the same time external dark shutters are utilized for solar control, it is advisable for someone interested to select from one of the two, in order to save costs apart from energy. Therefore, it is essential to ascertain the sensitivity each technique has to the others in order to end up to the ideal scenario that will combine energy savings and low costs.

Overall, the integration of all of the aforementioned energy saving techniques to the case study can decrease by half in the cooling loads and the produced CO_2 emissions from the base case scenario. The cost per tonne of CO_2 removed for the lifetime of the upgrading is approximately 75€, while the total amount of CO_2 removed during that time is about 350 tonnes.

Table 29 summarizes the total annual electricity savings followed by the CO_2 reduction they can cause if all of the aforementioned energy efficiency measures will be combined with the integration of the PV's.

	Average cost (€)	**Annual Electricity loads (kWh)**	**Annual Electricity loads per meter squared (kWh/m^2)**	**Total tonnes of CO2 produced (tn)**	**Total tonnes of CO2 removed (tn)**	**Percentage of CO2 reduction from existing case (%)**	**Life-time of energy efficiency measure (years)**	**Cost per tonne CO2 removed for the life-time of improv. (€/(tn*ys))**	**Total tonnes of CO2 removed for the improvement's life-time (tn*ys)**
Existing case	-	100.410	72	88	-	-	-	-	-
Improved case (1) (All energy efficient measures integrated)	25.895	87.058	62	76,3	11,7	13,3	26,25	84	307
PVs	357.000	56.190	40	49,2	38,7	44	25	369	968
Final Improved case (2) (Improved case (1) with PVs)	382.895	42.838	31	37,5	50,4	57,3	25,5	298	1.286

Table 29: Energy savings in electricity in correlation to the costs and the CO_2 removed from upgrading the fabric and installing PVs from the existing case

The final improved case (2) in which all of the energy efficient measures have been combined with the installation of PVs, leads to approximately 60% reductions of electricity from the base case, which for the case study corresponds to a percentage equal to **45%** of the total energy consumption. The annual CO_2 reductions from electricity are 50 tonnes corresponding to a percentage of 57,3% decrease from the existing case, whereas the cost of the final improved case approaches 383.000€. In this case, the cost per tonne of CO_2 removed over the lifetime of the upgrading is about 300€. The total CO_2 reductions reach 1.300 tonnes for the life-time of the improvements.

CHAPTER 11

11 CONCLUSIONS

Taking into account the ongoing tourism industry and the increasing levels of CO_2 emissions, the concept of sustainable tourism and the adoption of environmentally friendly techniques towards energy conservation in hotel buildings, are critical in order to combat climate change.

Based on actual monitored data concerning the energy consumption of a case study hotel in Kefalonia, a model of the building equivalent to the reality was designed using the Thermal Analysis Software. Several energy efficient techniques were examined in order to assess their effect on energy conservation. After a series of simulations, it appeared possible to reduce the energy consumption for cooling the building by half. According to the energy distribution of the hotel, this amount corresponds to 10% decrease from the total energy consumption. This was achieved by using several passive cooling techniques such as the adoption of night ventilation, solar control and by improving the building's fabric.

What follows highlights the main conclusions arising from the case study and which in some way constitute the answers to the key questions stated in the introduction of this report;

- The main factors affecting the energy consumption of a hotel are the building's design including its construction, the efficiency and the type of the cooling and lighting systems, the provided services, customer's and staff's behaviour and mainly the hotel's location which involves the prevailing climatic conditions, and its orientation.
- According to the results arising from the simulations carried out, the control of solar gains through shading devices such as overhangs or blinds and the use of high performance glazing, constitute methods that individually caused reductions by 10-15% to the annual cooling loads of the hotel.

However, the main decrease was observed by the use of night ventilation which caused a reduction by 35% of the total cooling loads from the existing case. Nevertheless, by introducing night ventilation it is essential to examine whether the obtained temperatures are within boundaries set as thermal comfort zone. The corresponding reductions in the total electricity consumption and CO_2 emissions by the application of all of the aforementioned techniques reached 14% and 13,3% respectively from the existing case, while the total cost per tonne of CO_2 removed during the life-time of the improvements is about 85€. Further energy savings may be achieved by using energy efficient appliances properly maintained and advanced fluorescent lighting and in combination with control systems for their operation, may lead to significant reductions in electricity consumption, which accounts a great percentage of the hotel's overall energy consumption.

- Furthermore, the installation of PVs was proposed. The installed area of $225m^2$ PVs in the hotel's roof facing south, can cover 40% of the electricity demands and will cost approximately 360.000€. The payback time assuming that the produced power will be sold to the grid and bought back from it in a much lower price, is 20 years. Despite the enormous initial cost of PVs, they can lead to significant reductions in the CO_2 emissions by 44% from the existing case. The total cost per tonne of CO_2 removed over the life-time of PVs in this case is 370€. Furthermore, Greece presents favourable conditions for their application, due to the abundant solar energy. Therefore, governments as well as local authorities should provide further subsidies in order to encourage hoteliers towards their installation.

Recapitulating, the combination of all of the aforementioned energy efficient techniques together with the installation of the proposed PV system can decrease significantly the electricity consumption by 60% from the existing case.

Simultaneously, the amount of CO_2 removed reaches 1.300 tonnes, while the total cost per tonne of CO_2 removed over the life-time of the upgrading is 300€.

To summarise, the installation and engagement to energy efficient measures and RES in the hotel sector can lead to significant reductions in energy consumption and CO_2 emissions, without comprising a compromise of comfort for the hotel occupants. Furthermore, it can help them at no additional cost to get accustomed to the energy saving technology and cultivate their environmental sensitivity. Therefore, the adoption of the value of sustainability in the tourism industry is a challenge that hoteliers should definitely exploit.

11.1 Future studies:

Next step of the dissertation would be to use Information and Communication Technologies in order to allow a dynamic allocation of energy loads in buildings. This would require:

- A sensing infrastructure (temperature, humidity, light sensors)
- A local area network
- Algorithms for dynamic assessment of measurements
- A distributed and not centralized energy management (cooling per room, lighting per room etc)
- A statistical study on the behaviour of occupants

An interesting question would be what is the cost in energy consumption for developing, producing and designing all these improvements so that to get an overall idea of what is being saved at the end of the day.

CHAPTER 12

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CHAPTER 13

13.1 Appendix A

Geographical distribution of Hellenic hotels

The geographical distribution of Greek hotels illustrate that the greatest number of hotels can be found in seven regions around Greece which gather more than 75% of the total number of hotels. These regions are Crete (16%), Central Greece (15%), Macedonia (15%), Dodecanese (12%), Cyclades (11%) and Ionian Islands (9%) (Green Lodges 2008) (Figure 52).

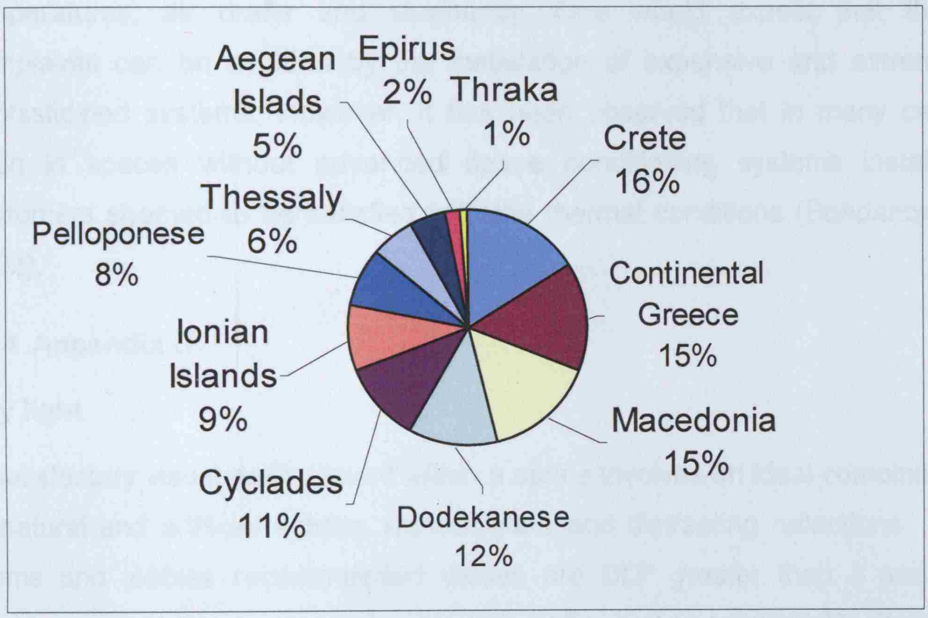


Figure 52: Percentage of hotels per area (source: Green lodges 2008)

13.2 Appendix B

The PMV model of Fanger

In this model Fanger assumes that the thermal sensation experienced by a person is a result of the physiological strain imposed on him by the environment defining as: "the difference between the internal heat production and the heat loss to the actual environment for a man kept at the comfort values for skin temperature and sweat production at the actual activity level" (Fanger 1972) (Comfortable Low Energy ARchitecture 2008).

13.3 Appendix C

The adaptive model of thermal comfort

Specifically, the occupants tend to adjust their thermal comfort preferences, behaviour and expectations to different indoor thermal conditions on the premise that the thermal changes do not concern extreme conditions and one would be given adequate time for adaptation (Bohdanowicz 2002).

Occupants complaints related to thermal comfort usually arise due to extreme temperatures, air drafts and stagnancy. One would expect that these complaints can be avoided by the installation of expensive and extremely sophisticated systems. However, it has been observed that in many cases even in spaces without advanced space conditioning systems installed, customers seemed to be satisfied with the thermal conditions (Bohdanowicz 2002).

13.4 Appendix D

Day light

A satisfactory visual environment within a space involves an ideal combination of natural and artificial lighting without glare and distracting reflections. For rooms and lobbies recommended values are DLF greater than 3 and for corridors and stairs a proposed value is a DLF equal to 1,5 (CIBCE, Guide A 2006, p.27).

Acoustics

The maximum suggested permissible background noise levels for hotel room is 20-30 noise rating (NR) (Where dBA ≈NR + 6), for corridors 30-35NR and for hotel lobbies 35-40 NR (CIBSE, Guide A 2006, p. 36).

Humidity

According to CIBSEs recommendations relative humidity accepted ranges are between 40 and 70% (CIBSE, Guide A 2006, p. 12).

13.5 Appendix E

Pictures of Kefalonia before the earthquake of 1953

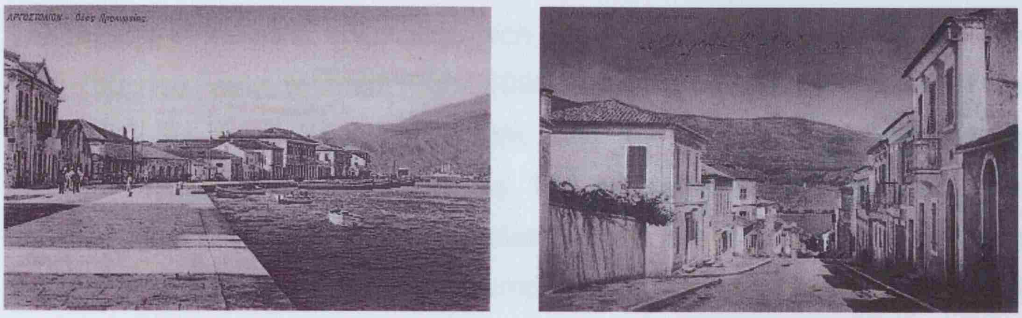


Figure 53: Kefalonia before the earthquake of 1953 (Source: www.kefalonitis.gr)

13.6 Appendix F

TAS results

The following chart illustrates the loads obtained from the TAS simulator within the hotel, for its operational months (Figure 54).

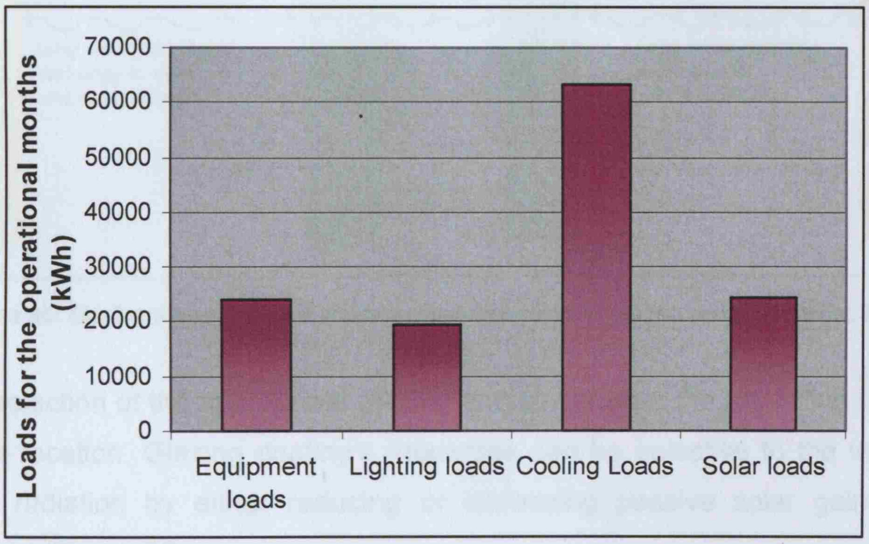


Figure 54: Loads for the operational months (May to mid- October) (Numbers copied from TAS without being adjusted to the system's efficiency)

13.7 Appendix G

High performance glazing

The regions of the solar spectrum which affect the building's design are visible (400-700 nm), near infrared (700- 4000 nm) and far infrared (greater than 8000 nm). As the solar radiation falls onto the glazing surface, it can be absorber, reflected either transmitted. The amount of absorbed radiation is converted into heat and can be re-radiated to the internal spaces of a building increasing significantly the internal temperatures (Davis 2008). The way heat is transferred through double skin glazing is presented in the following diagram (Figure 55).

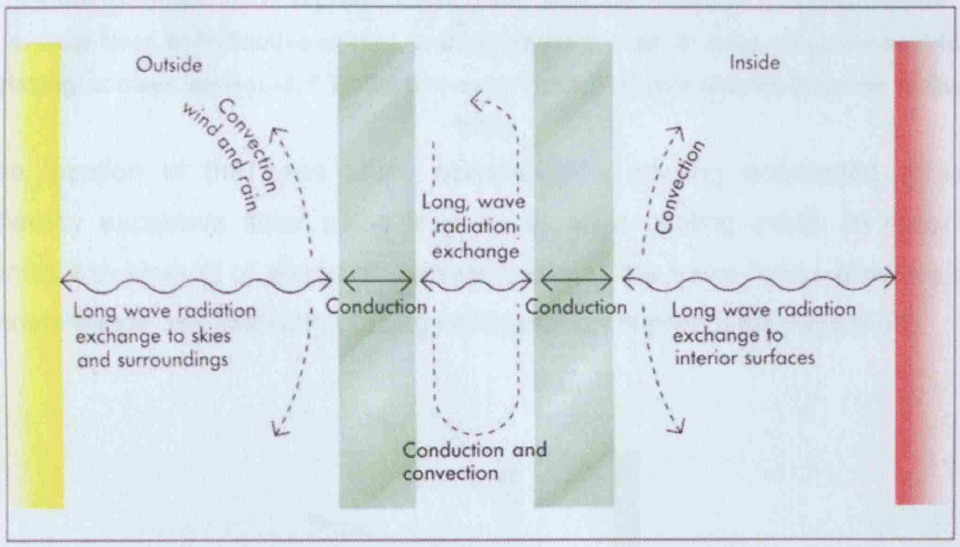


Figure 55: Mechanisms for heat transfer through double glazed units (Source: Button 1993)

The selection of the appropriate glazing should consider the prevailing climate of the location. Glazing coating's properties can be selective to the incident solar radiation by either reducing or increasing passive solar gains and daylight (Figure 56).

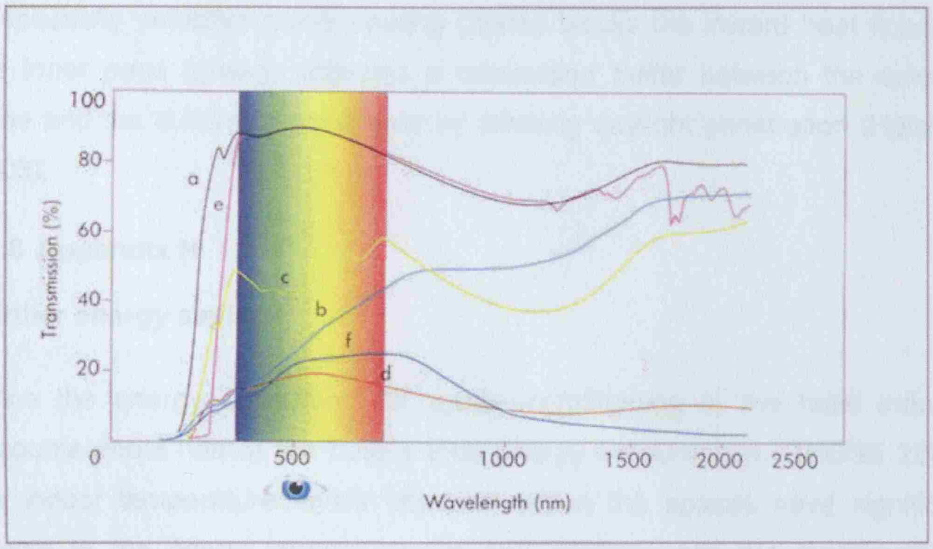


Figure 56: Spectrum of representative glass products showing UV transmission a: Clear float, b: Reflective coated, c: body tinted bronze, d: Gold reflective double glazing, e: clear laminated, f: Reflective solar control double glazing (Source: Button 1993)

The location of the case study constitutes a cooling dominated climate whereby excessive solar gains lead to massive cooling loads. In order to control the amount of absorbed radiation and at the same times allow visible transmittance, the following glazing configuration is proposed (Figure 57).

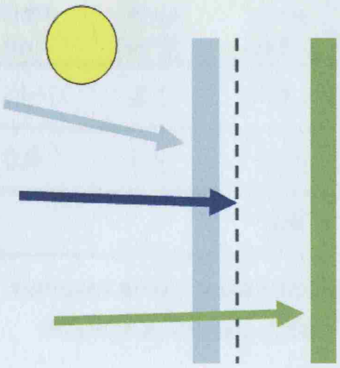


Figure 57: Cool glazing configuration (Source: Hutchins 2003)

The above diagram indicates the structure of a glazing for minimizing passive solar gains in which the outer pane (blue) absorbs solar infrared radiation.

A spectrally selective low-E coating (black) blocks the inward heat flow and the inner pane (green) activates a convection buffer between the external pane and the building's occupants by allowing daylight penetration (Hutchins 2003).

13.8 Appendix H

Further energy savings

Since the energy consumed for space conditioning in the hotel industry accounts about half of the hotel's total energy consumption (CHOSE 2001), the indoor temperature levels obtained within the spaces have significant effects to the overall energy profile and consequently the environmental impact of the hotel unit. For instance, according to Gillan (1999) 1oC reduction during the heating period in the room's temperature corresponds to a reduction of 10% in heating costs (Gillan 1999).

13.9 Appendix I

Cost analysis

Glazing		Element's dimensions		Element's Area	Total Area	min cost per meter squared incl. instalaton & VAT	max cost per meter squared incl. instalaton & VAT
Building element	Number	Height (m)	Width (m)	(m^2)	(m^2)	€/m^2	€/m^2
Balcony doors	55	2,1	1	2,1	115,5	100	150
Windows	15	1	0,9	0,9	13,5		
TOTAL					**129**	**12900**	**19350**

Table 30: Typical costs for sun-cool silver coated double glazing in Greece (Source: Pilkington Greece 2008)

Shading		**Overhang's dimensions**				**min cost per meter squared incl. instalaton & VAT**	**max cost per meter squared incl. instalaton & VAT**
Building element	**Number**	**Length (m)**	**Width (m)**	**Overhang's Area (m^2)**	**Total Area (m^2)**	**€/m^2**	**€/m^2**
Balcony doors	55	1,1	1	1,1	60,5	50	100
Window	15	0,6	0,9	0,54	8,1		
Entrance door	1	1,5	2	3	3		
TOTAL					**71,6**	**3580**	**7160**

Table 31: Typical costs for wooden structure with tile overhang in Greece (Source: Steganokataskevastiki 2008)

Roof Insulation		**min cost per meter squared incl. instalaton & VAT**	**max cost per meter squared incl. instalaton & VAT**
Building element	**Roof's total area (m^2)**	**€/m^2**	**€/m^2**
Roof	600	5	9
TOTAL	**600**	**3000**	**5400**

Table 32: Typical costs for fiber glass roof insulation in Greece (Source: Protectivo 2008)

13.10 Appendix J

Greek PV market

Since the investment costs of PV installations have been reduced due to the fall in the price of support structure and they do not require additional area of land, PV installations either connected or not to the electrical grid, constitute a reliable solution for electricity supply in tourist resorts (Haas cited in Bakos & Soursos 2001).

13.11 Appendix K

Electricity generation by fuel used

Electricity generation: by fuel used, EU comparison, 2001

Percentages and thousand gigawatt hours

	Nuclear	Coal & lignite	Petroleum products	Natural & derived gases	Hydro & wind[1]	Biomass & geothermal	Other fuels	All fuels (=100%) (thousand GWh)
Germany	*29*	*50*	*1*	*11*	*6*	*1*	*1*	582
France[2]	*77*	..	..	..	*14*	*1*	*8*	549
UK	*23*	*34*	*2*	*37*	*2*	*1*	-	386
Italy	*0*	*11*	*27*	*36*	*20*	*3*	*3*	279
Spain	*27*	*30*	*10*	*10*	*21*	*1*	*1*	238
Sweden	*45*	*1*	*2*	*1*	*49*	*2*	-	162
Netherlands	*4*	*25*	*3*	*62*	*1*	*4*	-	94
Belgium	*58*	*12*	*2*	*23*	*2*	*1*	*1*	80
Finland	*31*	*23*	*1*	*16*	*18*	*11*	-	74
Austria	*0*	*11*	*3*	*15*	*68*	*3*	-	64
Greece	*0*	*66*	*16*	*11*	*7*	*0*	-	54
Portugal	*0*	*29*	*20*	*16*	*31*	*4*	-	47
Denmark	*0*	*47*	*11*	*25*	*11*	*6*	*0*	38
Ireland	*0*	*37*	*21*	*37*	*5*	-	*0*	25
Luxembour	*0*	*0*	*0*	*22*	*73*	*5*	-	1
EU total	*33*	*25*	*6*	*17*	*15*	*2*	*2*	2,671

1 Includes pumped storage.

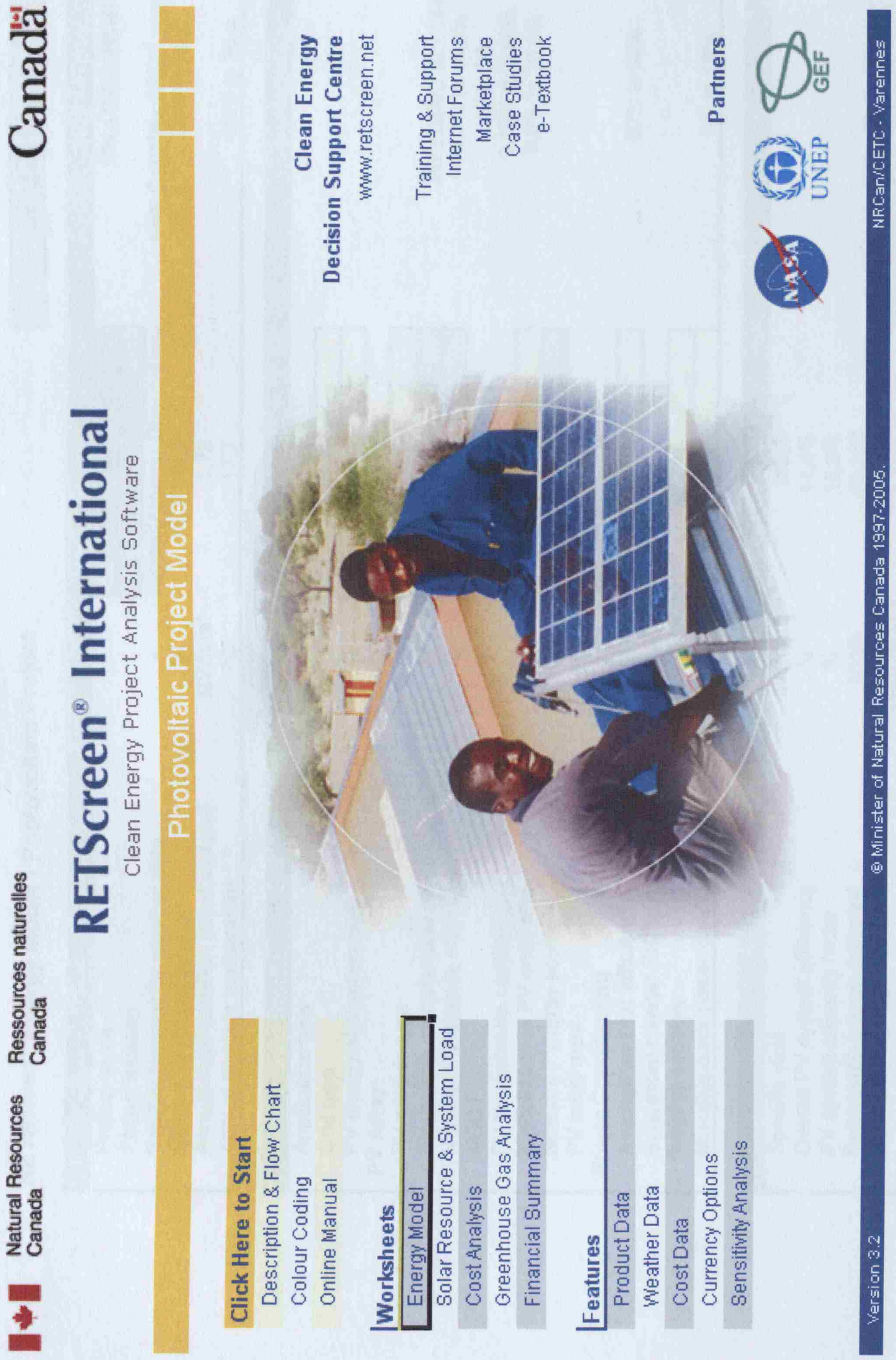
2 Breakdown of electricity produced from fossil fuels not reported. 'Other' therefore contains production from coal, natural gas and oil fired power stations.

Source: Eurostat

Table 33: Electricity generation by fuel used, EU comparison, 2001

13.12 Appendix L

Results from the RETScreen Software:



RETScreen® Energy Model - Photovoltaic Project

Training & Support

Site Conditions		Estimate	Notes/Range
Project name		**Sami Beach Hotel**	*See Online Manual*
Project location		**Kefalonia, Greece**	
Nearest location for weather data	-	Athinai(Athens) Observatory	➡ *Complete SR&SL sheet*
Latitude of project location	°N	38,0	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1,72	
Annual average temperature	°C	17,7	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	**On-grid**	
Grid type	-	Central-grid	
PV energy absorption rate	%	100,0%	
PV Array			
PV module type	-	mono-Si	
PV module manufacturer / model #		Sharp/ NT-185U1	*See Product Database*
Nominal PV module efficiency	%	14,2%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0,40%	0.10% to 0.50%
Miscellaneous PV array losses	%	5,0%	0.0% to 20.0%
Nominal PV array power	kWp	**32,01**	
PV array area	m²	225,4	
Power Conditioning			
Average inverter efficiency	%	90%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	28,8	
Inverter capacity	kW (AC)	5,0	
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (12,00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	196,2	
Overall PV system efficiency	%	11,4%	
PV system capacity factor	%	15,8%	
Renewable energy collected	MWh	49,133	
Renewable energy delivered	MWh	**44,220**	
	kWh	44.220	
Excess RE available	MWh	**0,000**	

Complete Cost Analysis sheet

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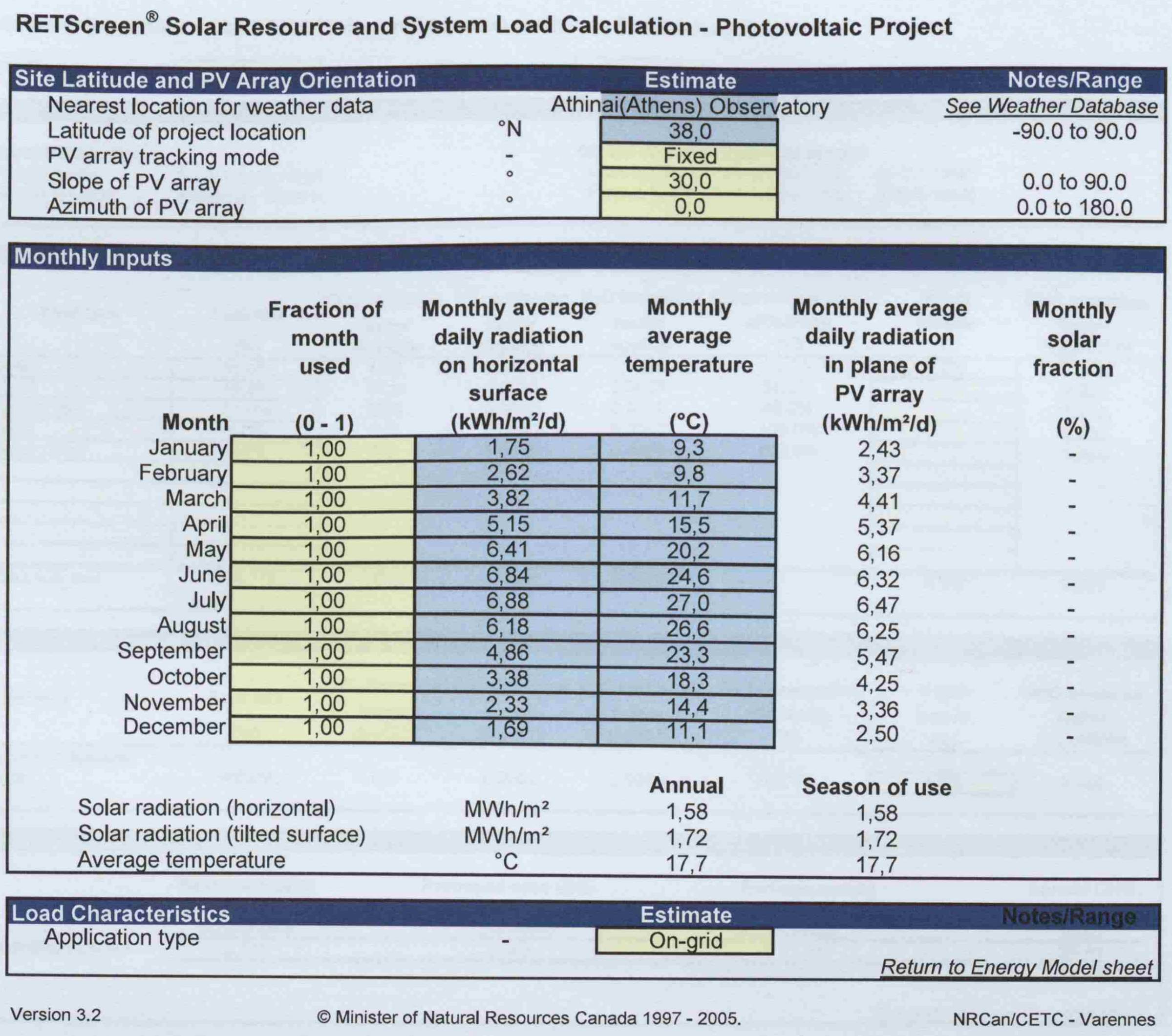

RETScreen® Solar Resource and System Load Calculation - Photovoltaic Project

Site Latitude and PV Array Orientation		Estimate	Notes/Range
Nearest location for weather data		Athinai(Athens) Observatory	*See Weather Database*
Latitude of project location	°N	38,0	-90.0 to 90.0
PV array tracking mode	-	Fixed	
Slope of PV array	°	30,0	0.0 to 90.0
Azimuth of PV array	°	0,0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	1,00	1,75	9,3	2,43	-
February	1,00	2,62	9,8	3,37	-
March	1,00	3,82	11,7	4,41	-
April	1,00	5,15	15,5	5,37	-
May	1,00	6,41	20,2	6,16	-
June	1,00	6,84	24,6	6,32	-
July	1,00	6,88	27,0	6,47	-
August	1,00	6,18	26,6	6,25	-
September	1,00	4,86	23,3	5,47	-
October	1,00	3,38	18,3	4,25	-
November	1,00	2,33	14,4	3,36	-
December	1,00	1,69	11,1	2,50	-

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1,58	1,58
Solar radiation (tilted surface)	MWh/m²	1,72	1,72
Average temperature	°C	17,7	17,7

Load Characteristics		Estimate	Notes/Range
Application type	-	On-grid	
			Return to Energy Model sheet

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RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Photovoltaic Project

Use GHG analysis sheet? Yes   Type of analysis: Standard

Background Information

Project Information

Project name	Sami Beach Hotel
Project location	Kefalonia, Greece

Global Warming Potential of GHG

1 tonne CH_4 = 21 tonnes CO_2 (IPCC 1996)
1 tonne N_2O = 310 tonnes CO_2 (IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Coal	66,0%	94,6	0,0020	0,0030	35,0%	8,0%	1,069
#6 oil	16,0%	77,4	0,0030	0,0020	30,0%		0,937
Natural gas	11,0%	56,1	0,0030	0,0010	45,0%		0,452
Wind	3,0%	0,0	0,0000	0,0000	100,0%		0,000
Large hydro	4,0%	0,0	0,0000	0,0000	100,0%		0,000
Electricity mix	100,0%	248,9	0,0064	0,0075		5,3%	0,905

Proposed Case Electricity System (Photovoltaic Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Electricity system							
Solar	100,0%	0,0	0,0000	0,0000	100,0%	4,0%	0,000

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)		Annual GHG emission reduction (t_{CO2})
Electricity system	0,905	0,000	42,451		38,41
			Net GHG emission reduction	t_{CO2}/yr	**38,41**

Complete Financial Summary sheet

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RETScreen® Financial Summary - Photovoltaic Project

Annual Energy Balance

Project name		Sami Beach Hotel			
Project location		Kefalonia, Greece	Nominal PV array power	kWp	32,01
Renewable energy delivered	MWh	44,220	Net GHG reduction	t_{CO2}/yr	38,41
Firm RE capacity	kW	-	Net GHG emission reduction - 25 yrs	t_{CO2}	960,28
Application type		On-grid			

Financial Parameters

Avoided cost of energy	€/kWh	0,380	Debt ratio	%	60,0%
RE production credit	€/kWh	0,015	Debt interest rate	%	8,5%
RE production credit duration	yr	25	Debt term	yr	25
RE credit escalation rate	%	2,0%			
GHG emission reduction credit	€/t_{CO2}	-	Income tax analysis?	yes/no	No
Energy cost escalation rate	%	5,0%			
Inflation	%	2,5%			
Discount rate	%	9,0%			
Project life	yr	25			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	2,8%	€	10.000	O&M	€	880
Development	4,2%	€	15.000	Fuel	€	-
Engineering	15,4%	€	55.000	Debt payments - 25 yrs	€	20.930
Energy equipment	51,6%	€	184.058	**Annual Costs and Debt - Total**	**€**	**21.810**
Balance of equipment	21,2%	€	75.557			
Miscellaneous	4,9%	€	17.390	**Annual Savings or Income**		
Initial Costs - Total	100,0%	**€**	**357.005**	Energy savings/income	€	16.804
Incentives/Grants		€	-	RE production credit income - 25 yr:	€	663
				Annual Savings - Total	**€**	**17.467**
Periodic Costs (Credits)						
Inverter Repair/Replacement		€	50.000	Schedule yr # 12,24		
		€	-			
		€	-			
End of project life -		€	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	0,3%			
After-tax IRR and ROI	%	0,3%	Calculate GHG reduction cost?	yes/no	No
Simple Payback	yr	21,5			
Year-to-positive cash flow	yr	22,0	Project equity	€	142.802
Net Present Value - NPV	€	(118.923)	Project debt	€	214.203
Annual Life Cycle Savings	€	(12.107)	Debt payments	€/yr	20.930
Benefit-Cost (B-C) ratio	-	0,17	Debt service coverage	-	(1,79)

Yearly Cash Flows

Year #	Pre-tax €	After-tax €	Cumulative €
0	(142.802)	(142.802)	(142.802)
1	(3.512)	(3.512)	(146.314)
2	(2.639)	(2.639)	(148.952)
3	(1.722)	(1.722)	(150.674)
4	(759)	(759)	(151.433)
5	253	253	(151.180)
6	1.315	1.315	(149.865)
7	2.430	2.430	(147.435)
8	3.601	3.601	(143.834)
9	4.831	4.831	(139.002)
10	6.123	6.123	(132.879)
11	7.480	7.480	(125.399)
12	(58.340)	(58.340)	(183.739)
13	10.401	10.401	(173.339)
14	11.972	11.972	(161.367)
15	13.622	13.622	(147.745)
16	15.354	15.354	(132.391)
17	17.174	17.174	(115.217)
18	19.085	19.085	(96.133)
19	21.091	21.091	(75.041)
20	23.198	23.198	(51.843)
21	25.411	25.411	(26.432)
22	27.735	27.735	1.304
23	30.176	30.176	31.479
24	(57.698)	(57.698)	(26.219)
25	35.430	35.430	9.211

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