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PROCCESS EQUIPMENT DESIGN LABORATORY

Analysis of 3 Decades Temperature Data for Athens and Thessaloniki, Greece Impact of Temperature Changes on Energy Consumption for Heating and Cooling of Buildings

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Introduction (1/4)

The topic of climate change has attracted widespread attention in recent years.

The reasons for climate change are complex and there are various opinions about the causes in the scientific community.

The main cause, commonly accepted nowadays, is the emissions from buildings, business, agriculture and transport.

In all these activities non-renewable energy sources (liquid, gas and solid fuels) are used and greenhouse gases are produced.

Introduction (2/4)

Recently, numerous studies have been conducted around the world into the impacts of global warming on

- the changes of ambient air temperature
- the energy consumption in built environment
- electric energy demand
- related GHG emissions

These studies analyze historical data or estimate the climate over the next years, by using computational models of the world climate system.

Introduction (3/4)

According to IPCC (Intergovernmental Panel on Climate Change) Climate change report 2007:

- warming in the last 100 years has caused about a 0.74°C increase in global average temperature
- eleven of the twelve years in the period 1995–2006 rank among the top 12 warmest years in the instrumental record (since 1880)
- Further warming will continue if emissions of greenhouse gases continue.

Introduction (4/4)

The purpose of this work is:

- ❑ to present the results of a 30-year (1983-2012) statistical analysis of ambient air temperature data for the two major Greek cities, Athens and Thessaloniki
- ❑ to present a reference document on the recent–past and present air temperature variations for use in energy application-oriented studies
- ❑ to present the impact of temperature data changes on the energy consumption of buildings

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Temperature data

Hourly dry bulb temperature data were made available from the meteorological stations

- ❑ of the National Observatory of Athens (NOA)
- ❑ of the Institute of Meteorology and Climatology of the Aristotle University of Thessaloniki (IMC/AUTh)

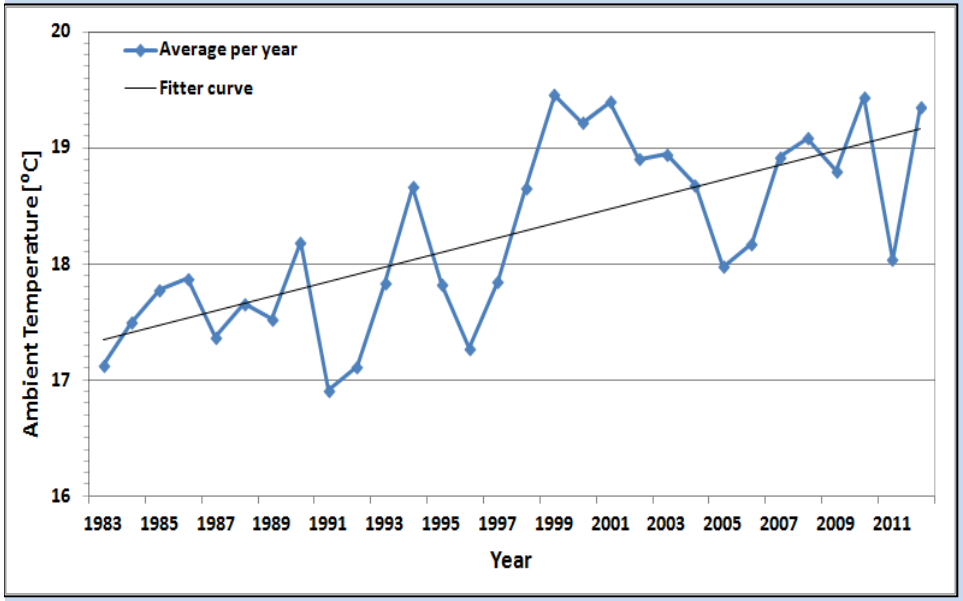
Both stations lie near the town center but they are isolated from heavy traffic and densely built areas.

10 Years Average Annual Temperatures

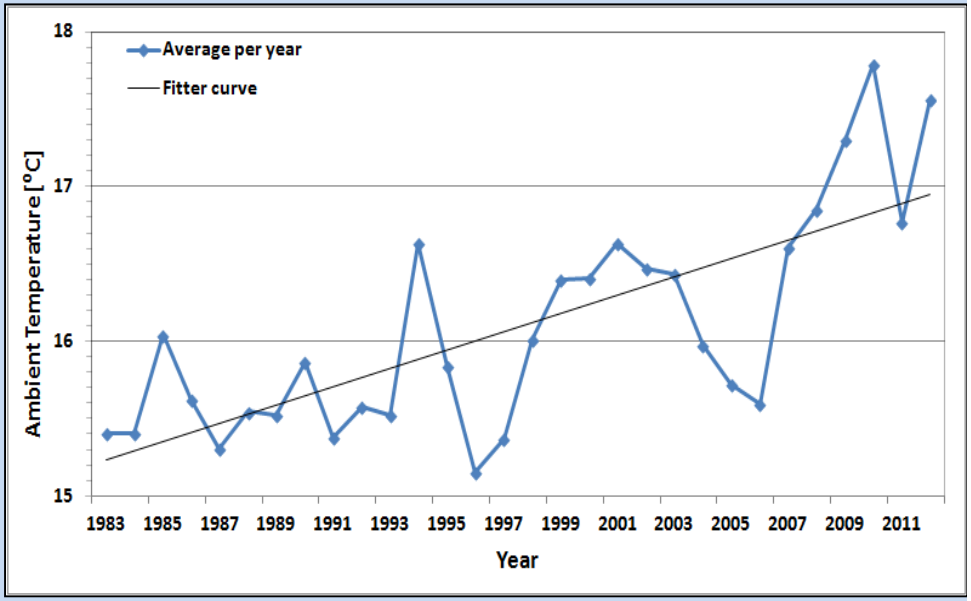
	Athens			Thessaloniki		
Period	1983-1992	1993-2002	2003-2012	1983-1992	1993-2002	2003-2012
Annual	**17.50**	**18.51**	**18.74**	**15.57**	**16.04**	**16.66**

The 10 Years average annual temperature:
In Athens increased 1^0C from the first to the second decade and 0.2^0C from the second decade to the third.
In Thessaloniki the increase was 0.5^0C from the first to the second decade and 0.6^0C from the second to the third decade.

Annual and 5 Years Average Temperatures



Athens



Thessaloniki

There is an upward trend of the annual and 5 Years average temperature for both cities.
There is a constant increase in monthly average temperatures for both cities

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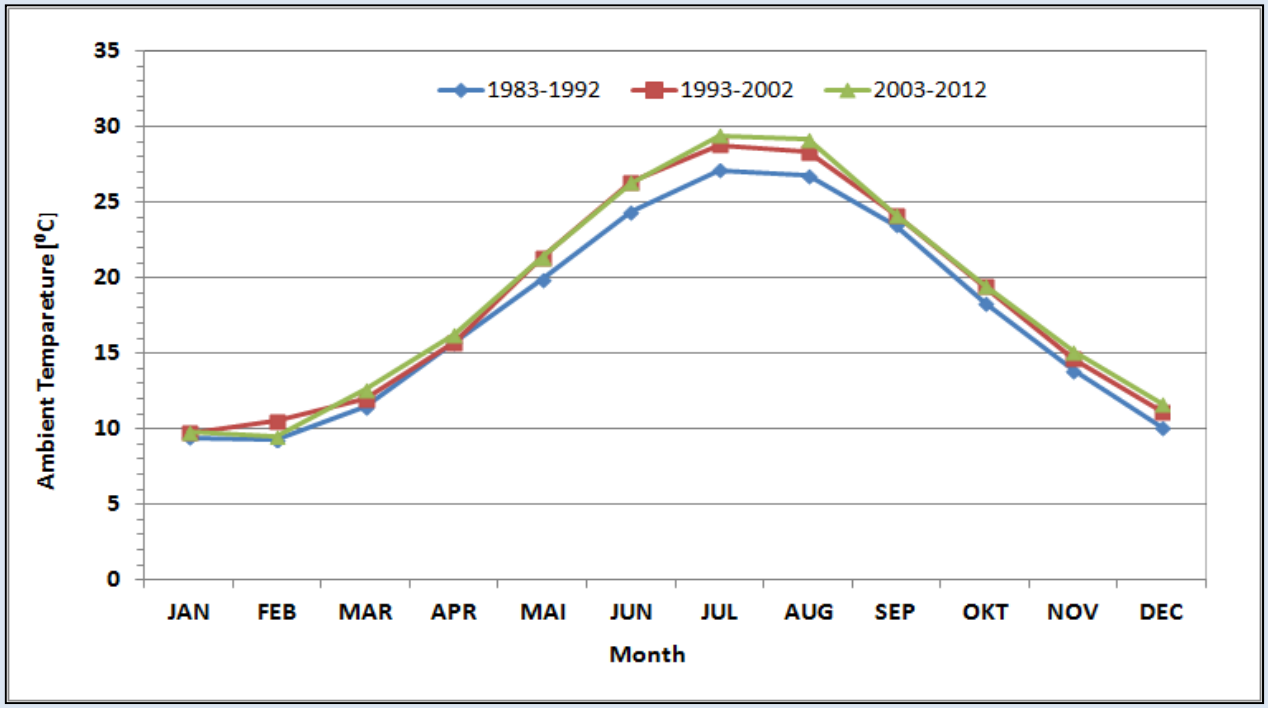
Monthly Average Temperatures



Athens

During **summer** the increase ranges:
from **0.63 K** in September to **2.43 K** in August
During **winter** the increase ranges:
from **0.18K** in February to **1.51K** in December.

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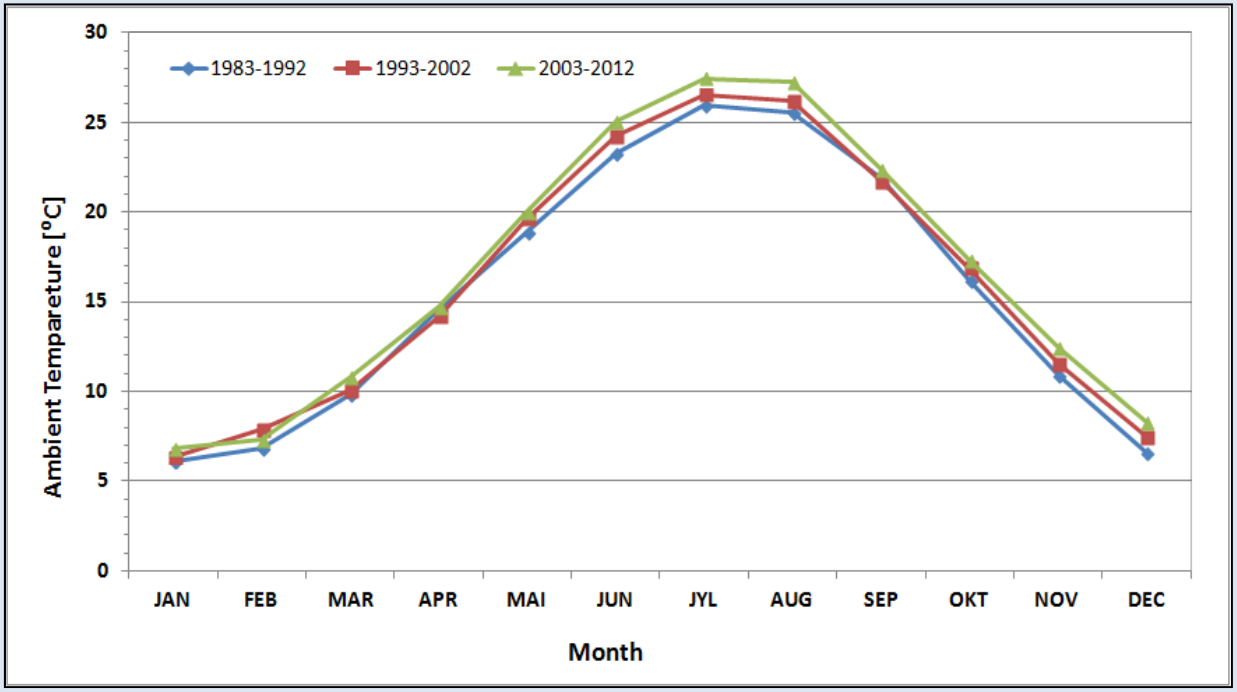
Monthly Average Temperatures



Thessaloniki

During **summer** the increase ranges:
from **0.42 K** in September to **1.74 K** in August
During **winter** the increase ranges
from **0.16 K** in April to **1.70 K** in December

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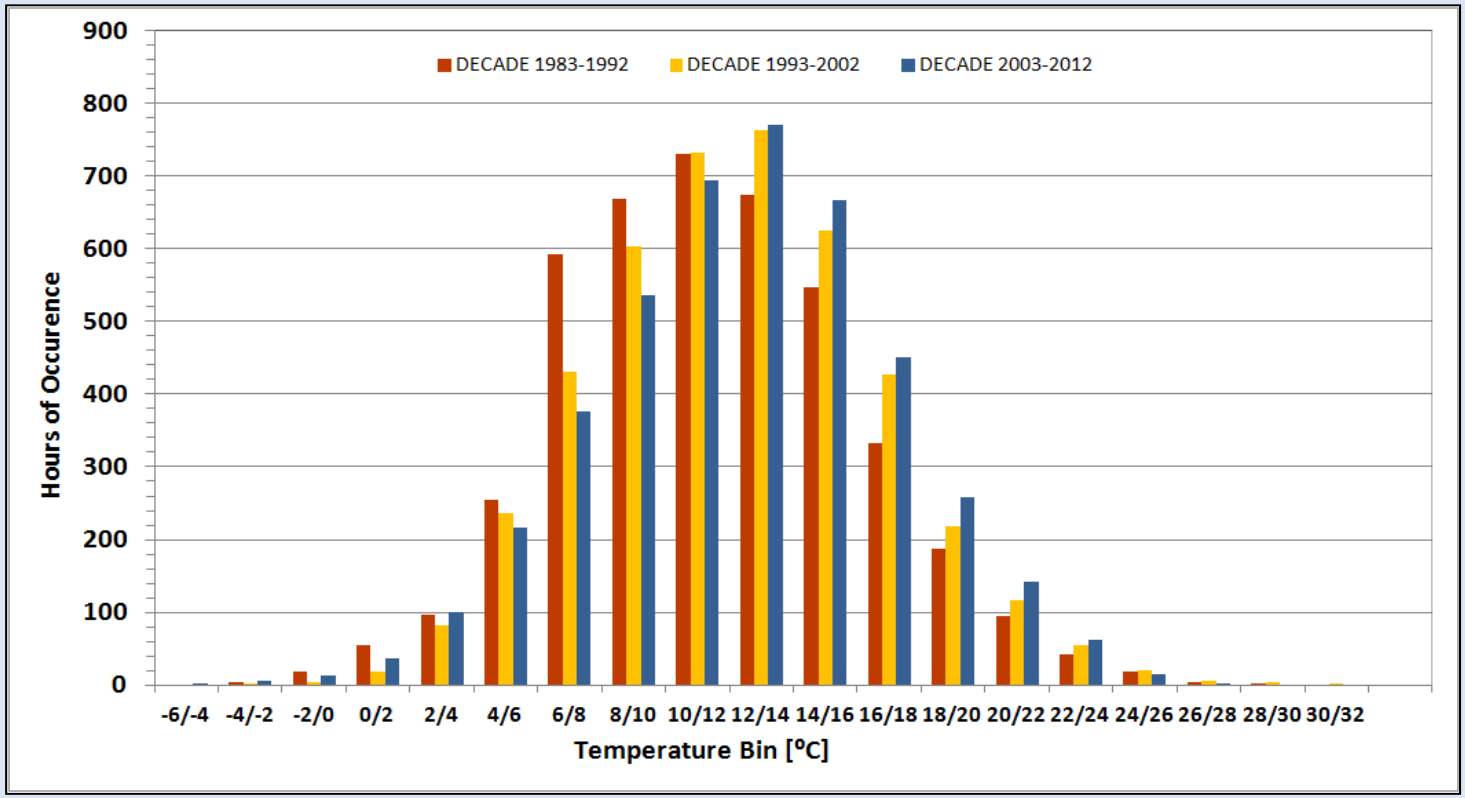
Temperature Bin Data - Athens



Athens Heating Period

The frequency of occurrence of the low temperature bins (<6/8°C) reduced from 1021 to 748 h

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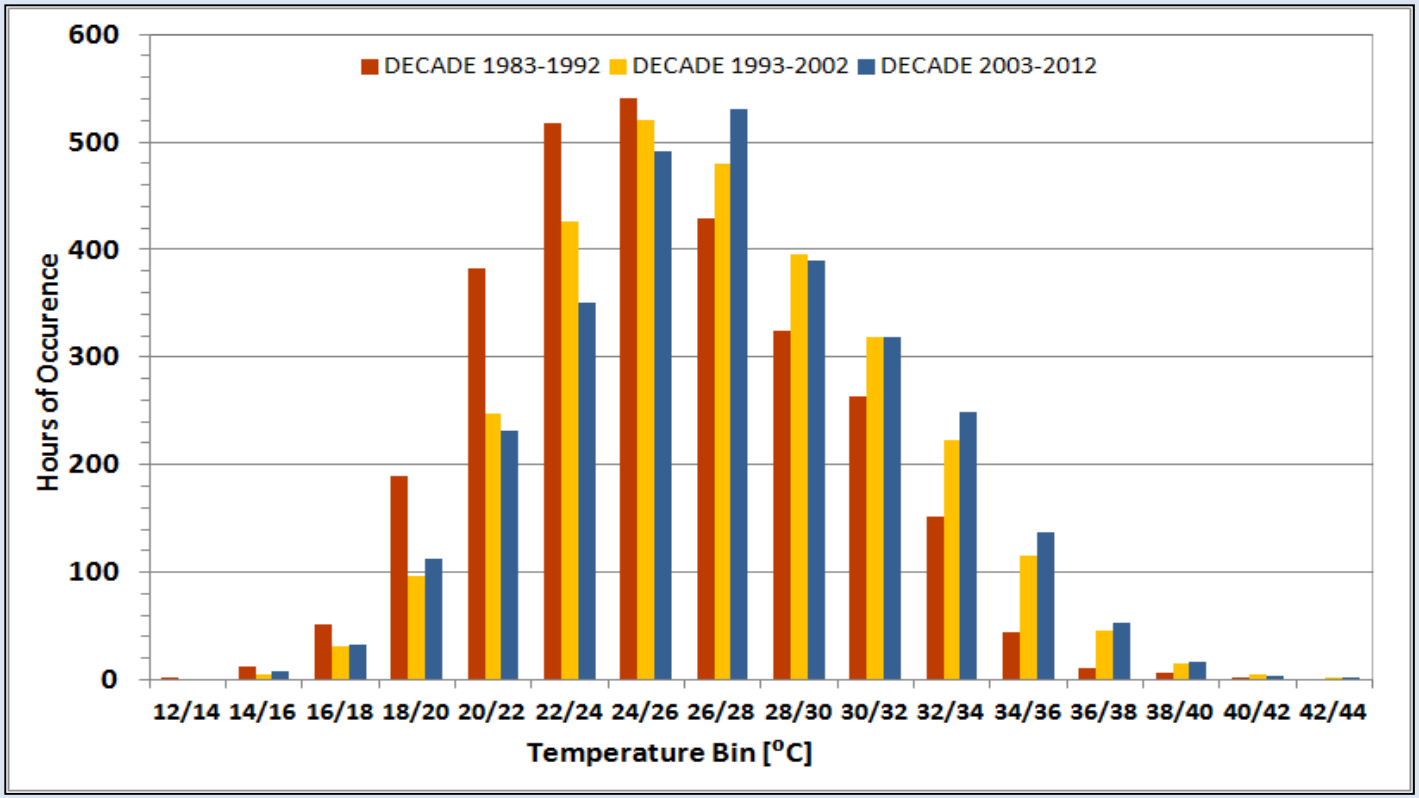
Temperature Bin Data - Athens



Athens Cooling Period

The frequency of occurrence of the peak temperature bins (>32/34°C) increased from 477 to 779 h

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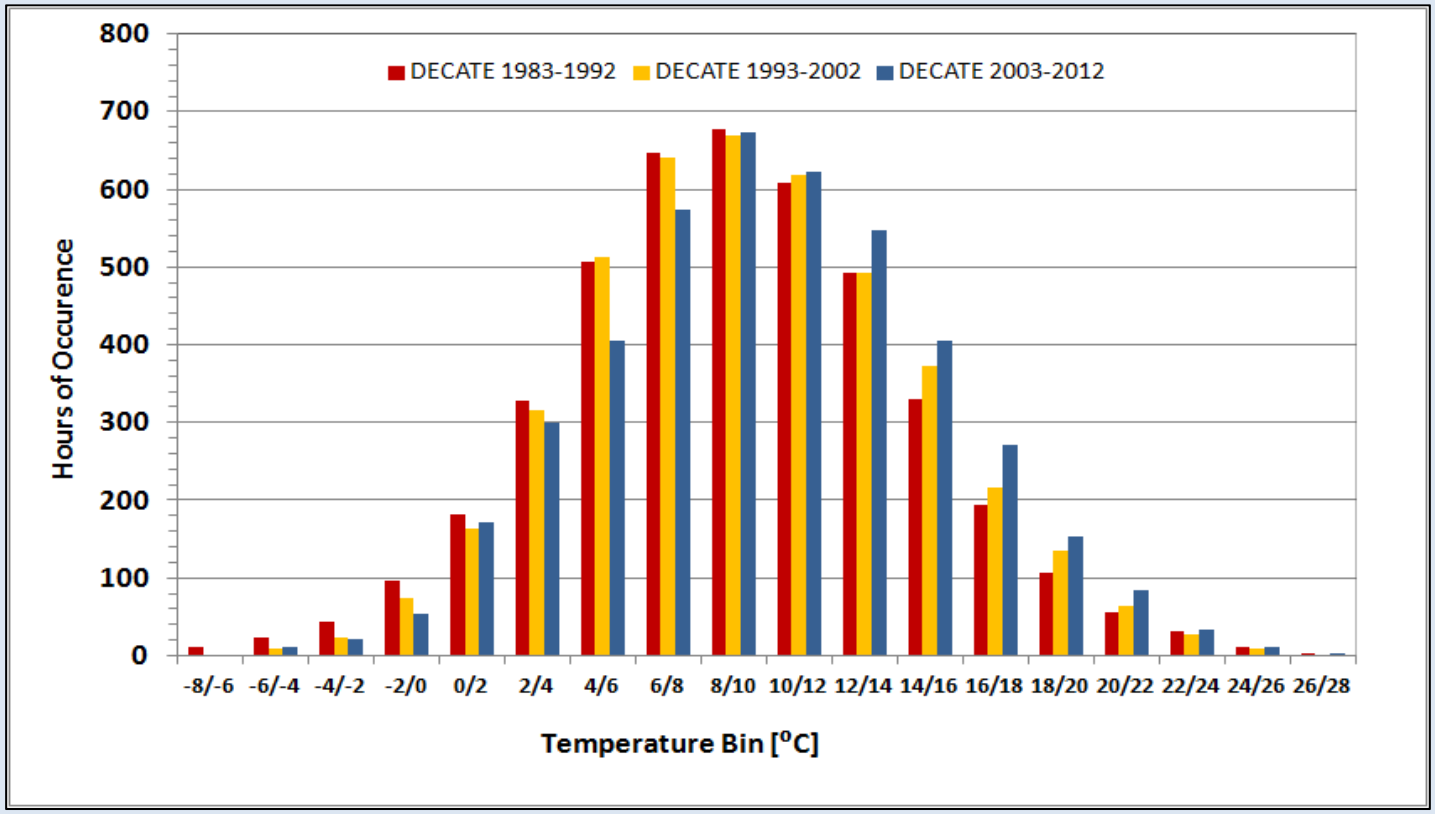
3. Temperature Bin Data - Thessaloniki



Thessaloniki Heating Period

The frequency of occurrence of the low temperature bins (<6/8°C) reduced from 1836 to 1537 h.

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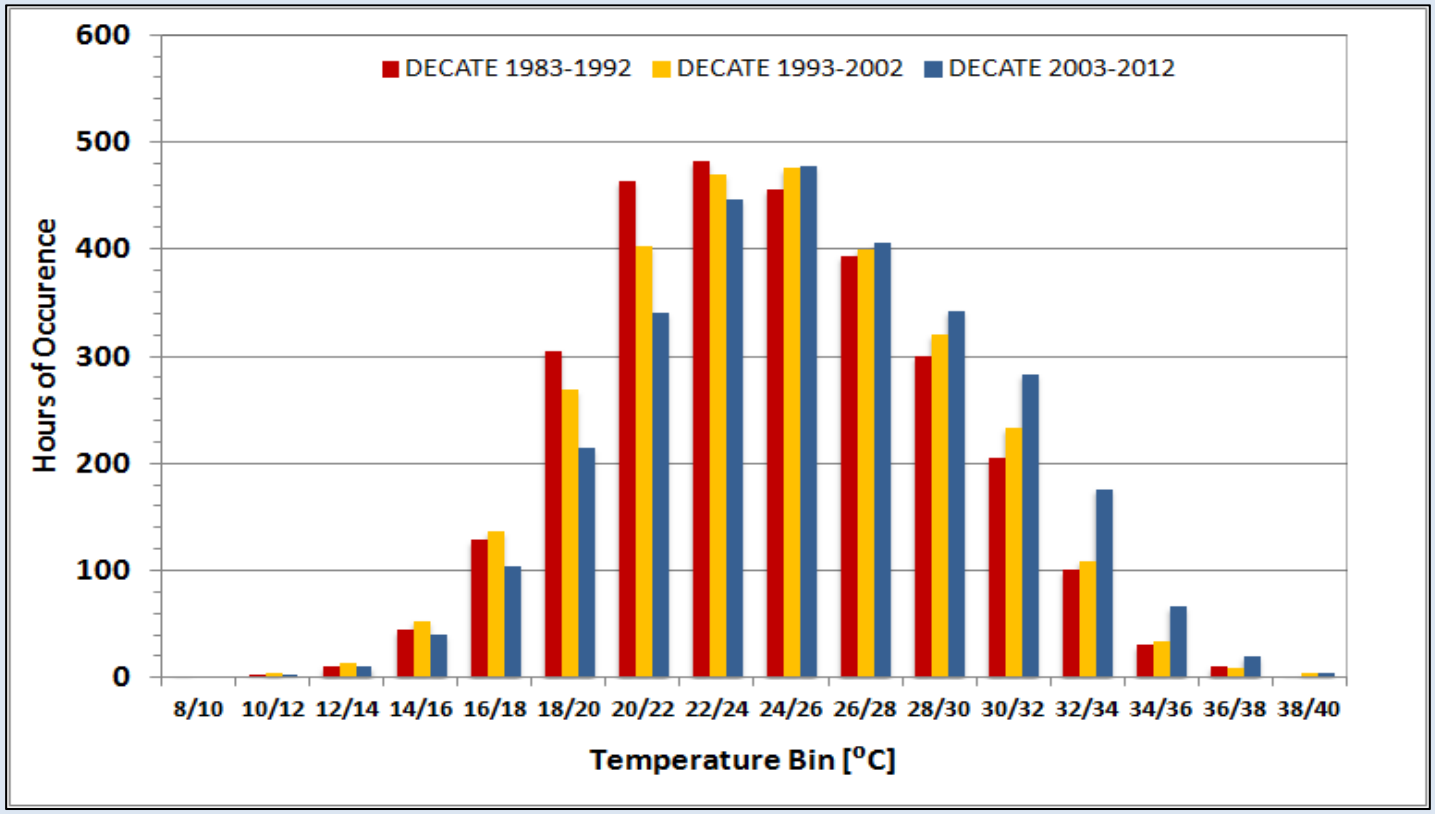
Temperature Bin Data - Thessaloniki



Thessaloniki Cooling Period

The frequency of occurrence of the peak temperature bins (>32/34°C) increased from 141 to 266 h

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Temperature Bin Data

- In both cities the distribution shifts to the right
- In every new decade
  the frequency (h) of the low temperature bins is steadily decreased
  the frequency of the high temperature bins is increased
- The most frequent temperature bin, in the cooling period was 24/26°C which increased to 26/28°C
- The most frequent temperature bin in the heating period was 10/12°C and increased to 12/14°C

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Energy Demands for Heating and Cooling

In order to quantify the effect of temperature data changes on the energy consumption of buildings, the energy demands of an office building were estimated for heating and cooling.

The office building was simulated by using 3 decades (1983-1992, 1993-2002 and 2003-2012) temperature bin data of both cities.

Energy requirements account for sensible loads only, since the data analysis presented in this paper refers only to dry-bulb temperature data.

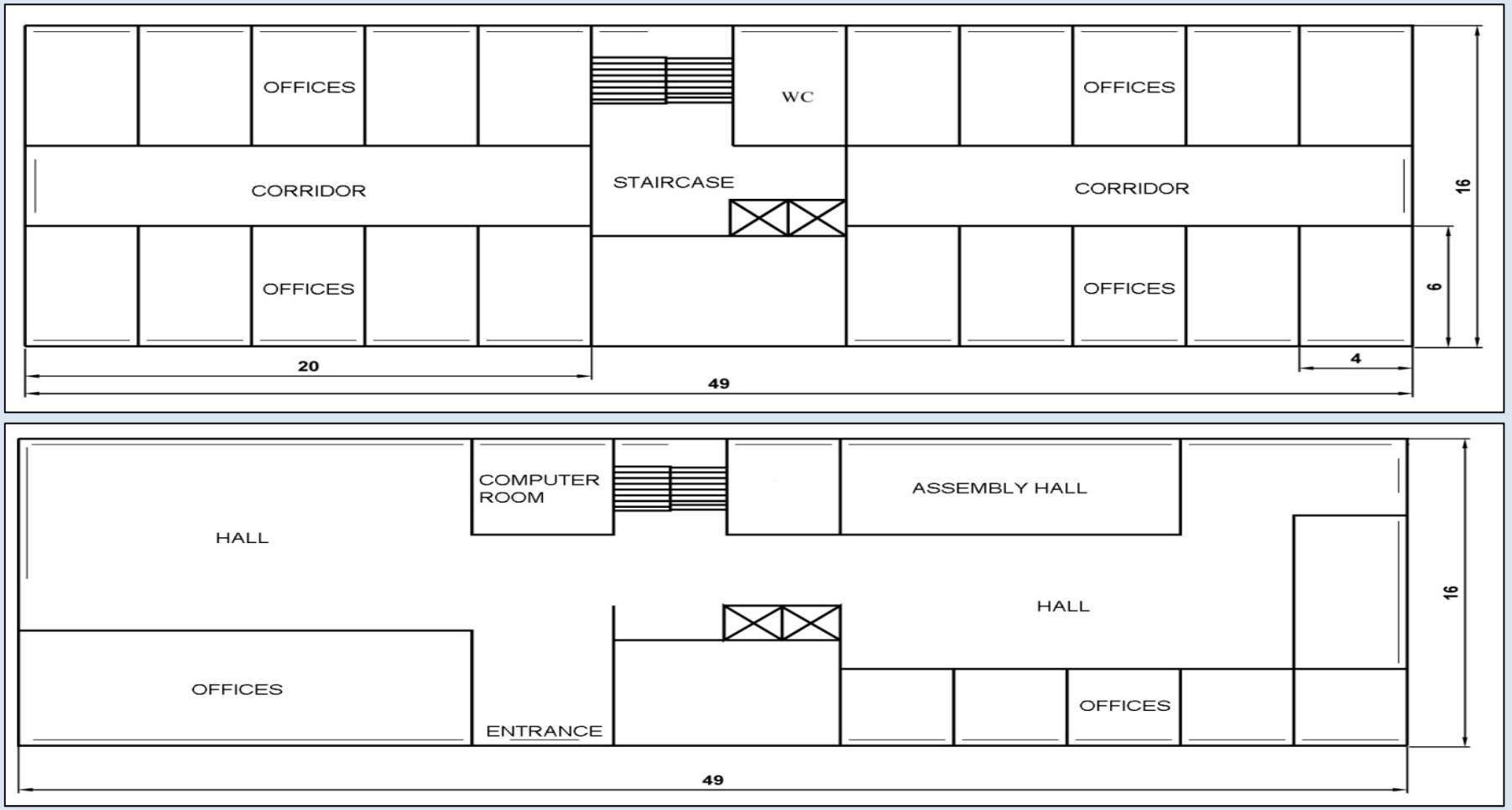
Energy Demands for Heating and Cooling

The building chosen for this study is typical building of the university campus in Thessaloniki

- rectangular shape
- dimensions16x45m
- 9 floors with offices
- a ground floor (main entrance, offices, computer room)
- a basement which houses the utilities

The two main elevations of the building are oriented to the north and to the south

Energy Demands for Heating and Cooling



Plan view of the building's typical floor and ground floor

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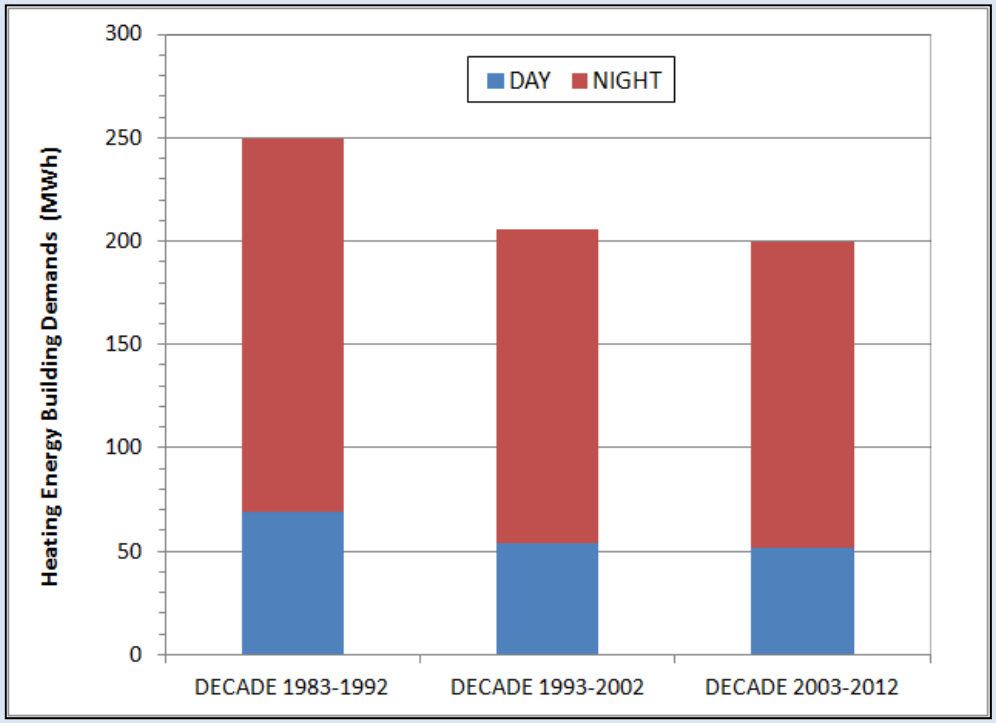
Energy Demands for Heating



Energy Demands for Heating (Athens)

(1983-1992)→(1993-2002)

17.6% reduction

(1993-2002)→(2003-2012)

2.8% reduction

Total heating demands reduction = **19.9%**

(from 1st to 3rd decade)

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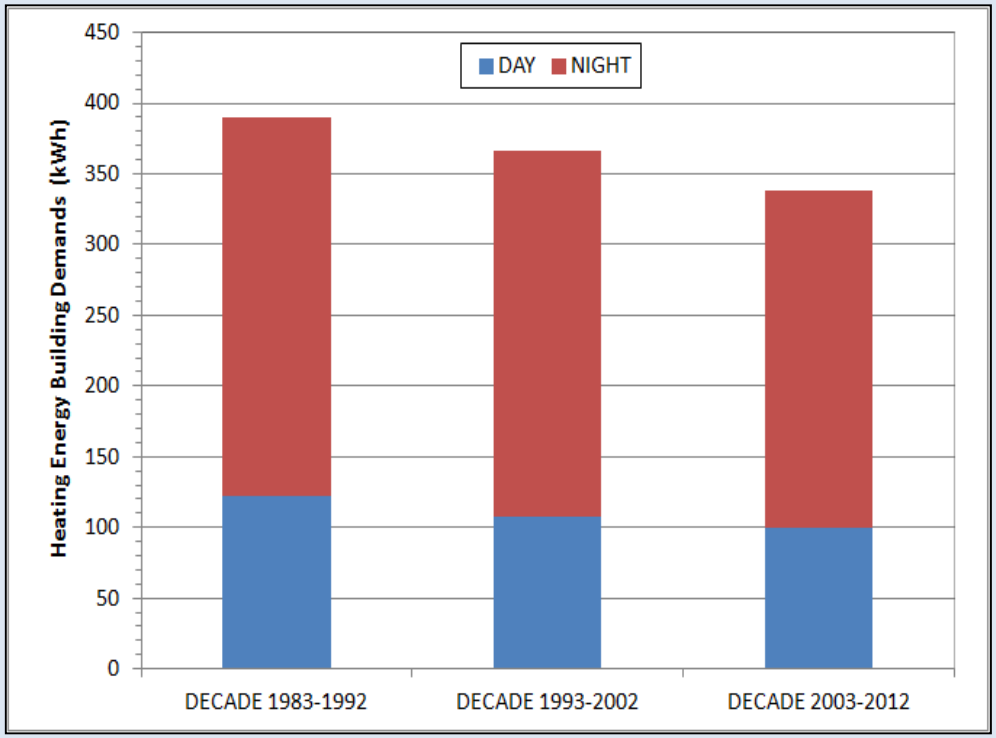
Energy Demands for Heating



Energy Demands for Heating (Thessaloniki)

(1983-1992)→(1993-2002)

6.2% reduction

(1993-2002)→(2003-2012)

7.4% reduction

Total heating demands reduction = **13.2%**

(from 1st to 3rd decade)

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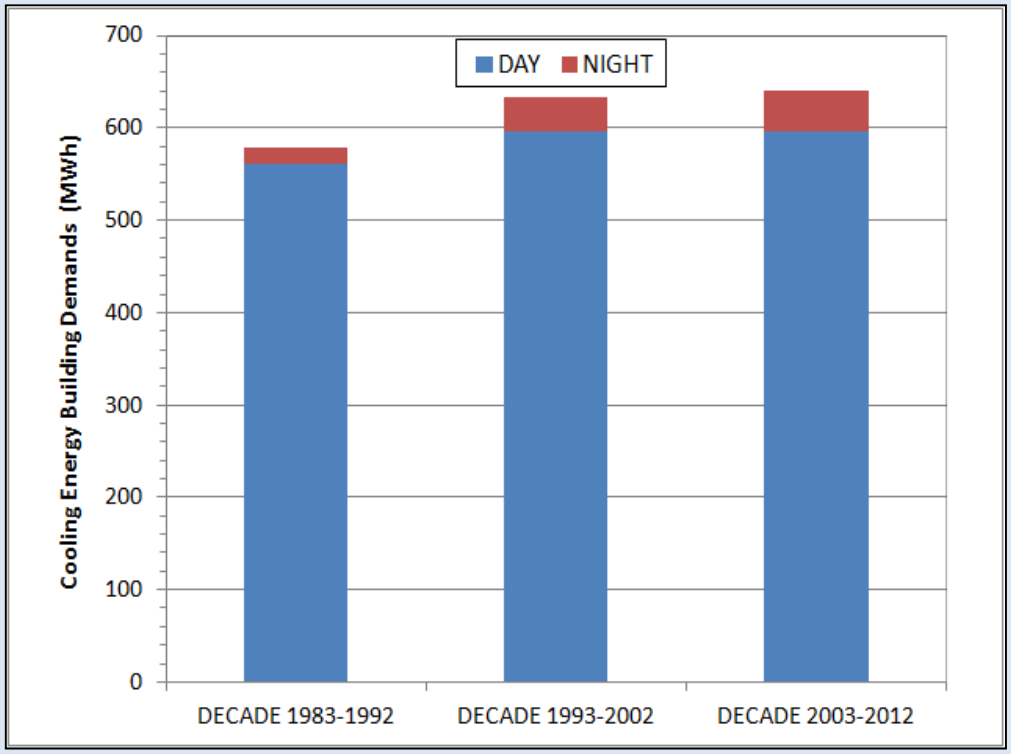
Energy Demands for Cooling



Energy Demands for Cooling (Athens)

(1983-1992)→(1993-2002)

9.6% increase

(1993-2002)→(2003-2012)

0.9% increase

Total cooling demands increase = **10.6%**

(from 1st to 3rd decade)

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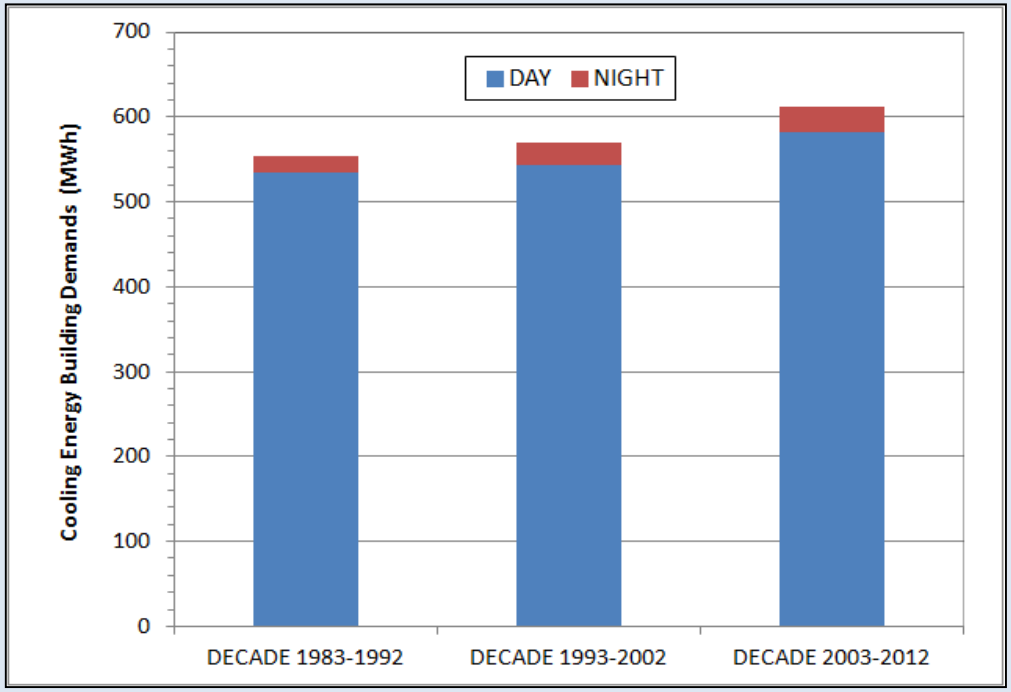
Energy Demands for Cooling



Energy Demands for Cooling (Thessaloniki)

(1983-1992)→(1993-2002)

2.8% increase

(1993-2002)→(2003-2012)

7.4% increase

Total cooling demands increase = **10.4%**

(from 1st to 3rd decade)

Conclusions (1/3)

- The indication of climate change towards **milder winters and hotter summers** in the two cities is confirmed

- The ambient temperature has a significant **increasing linear trend** during the last 30 years

- The 10-year annual average temperature, from the first to the third decade, **increased** 1.2^{0}C for Athens and 1.1^{0}C for Thessaloniki

- The average monthly and 5-year temperature values display the same increasing trend as well

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Conclusions (2/3)

- In every decade **the frequency** of occurrence (in **h**)
  - of the low temperature bins is steadily **decreased**
  - of the high temperature bins is **increased**

- The consequence of climate change has strong effects on buildings' energy requirements

- Energy calculations for a typical office building showed a continuous, from decade to decade, **decrease** of the energy requirements for heating and a permanent **increase** of the energy requirements for cooling

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Conclusions (3/3)

➢Changes in the ambient air-temperature will have significant consequences upon:

- o the demand for electricity
- o the potential of using outdoor air for “free cooling”
- o the performance of HVAC equipment (chillers and heat pumps)

➢The changing climate will need to be reflected in future building design (i.e. **temperature data** input for **dimensioning HVAC systems** and for **energy behavior calculations** must be periodically re-examined and reviewed)

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Thank You
for your Attention

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