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Session HS5.6: Harnessing the resources offered by sun, wind and water:  
control and optimization

### **Analysis of the electricity demand of Greece for optimal planning of a large-scale hybrid renewable energy system**



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# 1. Abstract

The Greek electricity system is examined for the period 2002-2014. The demand load data are analysed at various time scales (hourly, daily, seasonal and annual) and they are related to the mean daily temperature and the gross domestic product (GDP) of Greece for the same time period. The prediction of energy demand, a product of the Greek Independent Power Transmission Operator, is also compared with the demand load. Interesting results about the change of the electricity demand scheme after the year 2010 are derived. This change is related to the decrease of the GDP, during the period 2010-2014. The results of the analysis will be used in the development of an energy forecasting system which will be a part of a framework for optimal planning of a large-scale hybrid renewable energy system in which hydropower plays the dominant role.

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## 2. Background

Some studies on the electricity demand of Greece and Cyprus follow:

- Psiloglou et al. (2009) present an analysis of the electricity demand in Athens, the capital city of Greece, for the time period 1997–2001. The electricity demand in Athens is about the 50% of the total electricity demand in Greece.
- Tsani (2010) investigates the relationship between the energy consumption and economic growth in Greece for the time period 1960–2006.
- Andrianesis et al. (2011) provide an overview of the Greek wholesale electricity market.
- Koroneos et al. (2011) analyse the energy and exergy utilization in the energy sector of Greece for the time period 1990–2004.
- Marques et al. (2014) analysed the interactions between electricity generation sources and industrial production in Greece for the time period 2004–2013.
- Zachariadis and Pashourtidou (2007) present an empirical analysis of electricity consumption in Cyprus for the time period 1960–2004.

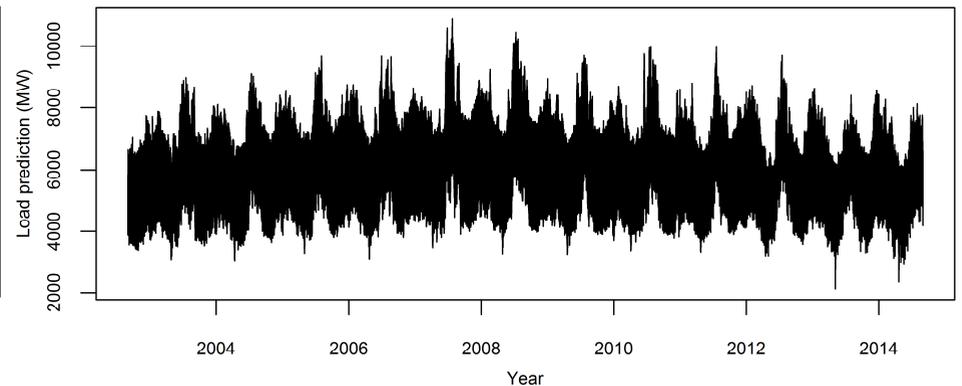
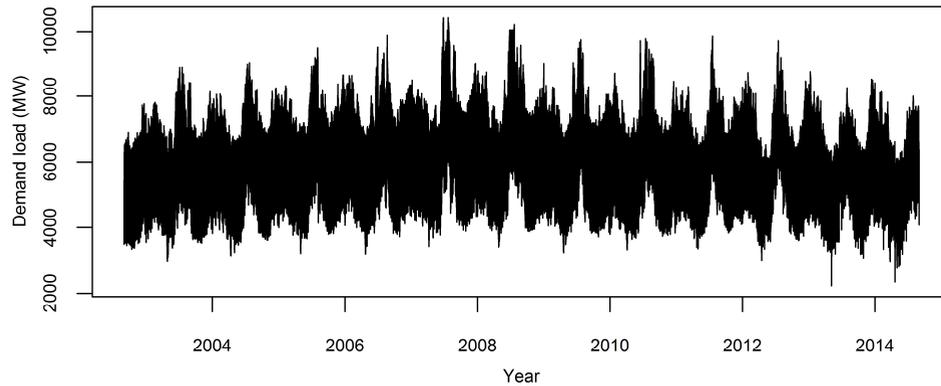
In this presentation we analyse the electricity demand in Greece for the time period 2002–2014.

# 3. Demand load and load prediction data

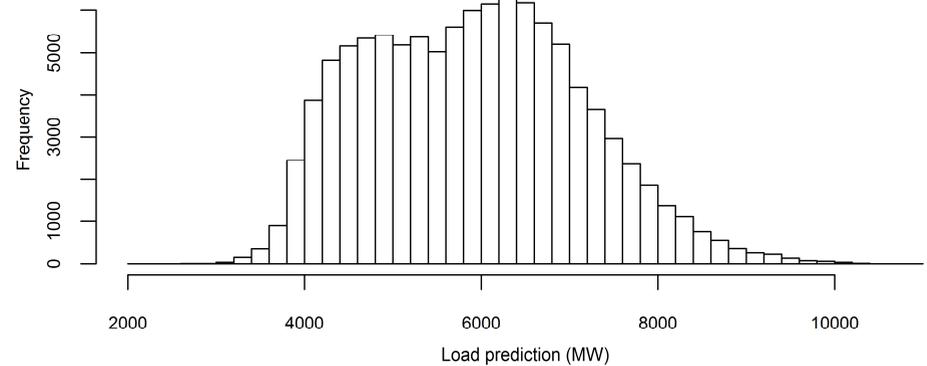
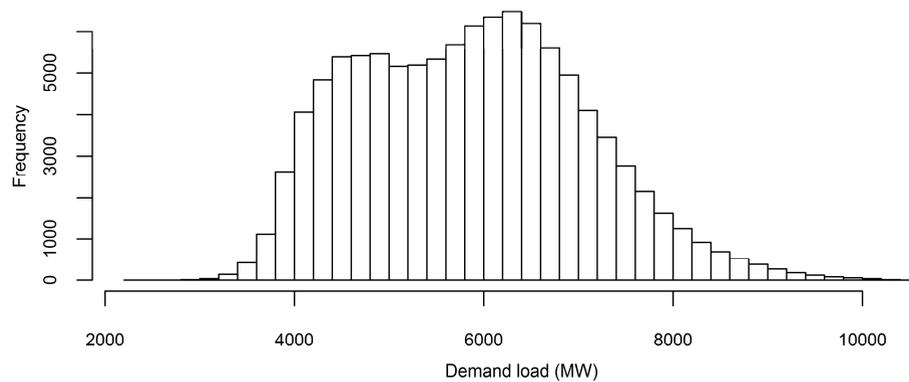
Hourly values of demand load

Hourly values of load prediction

Annual seasonality is evident



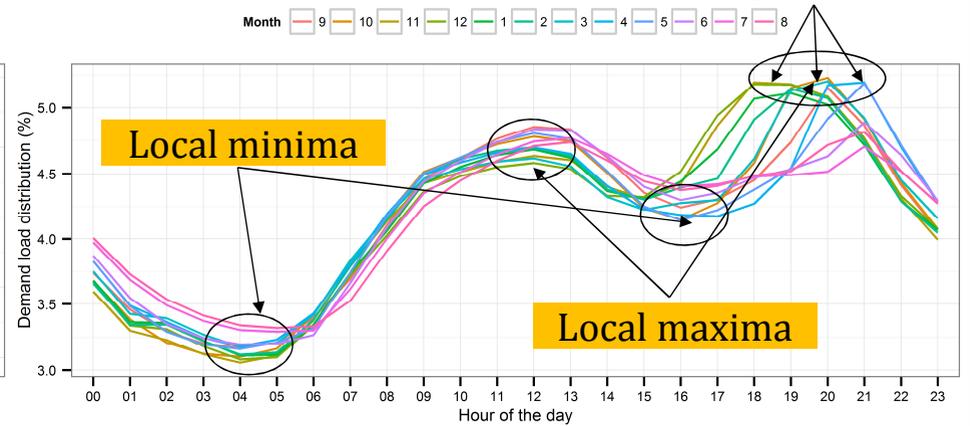
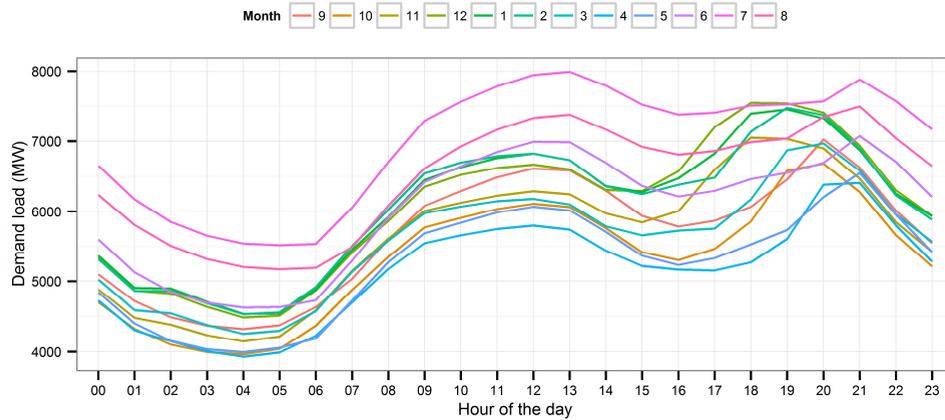
Histograms of hourly values



Data source: Independent Power Transmission Operator (2015)

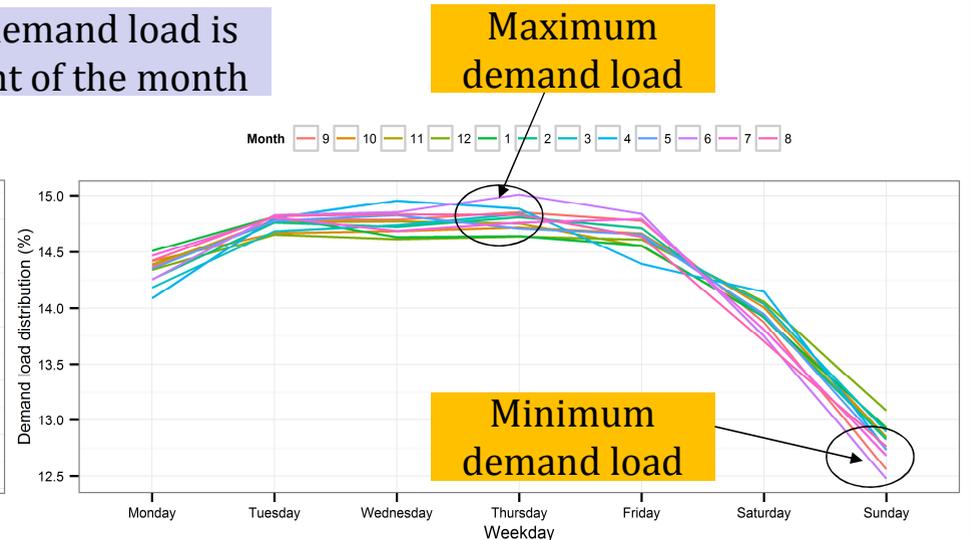
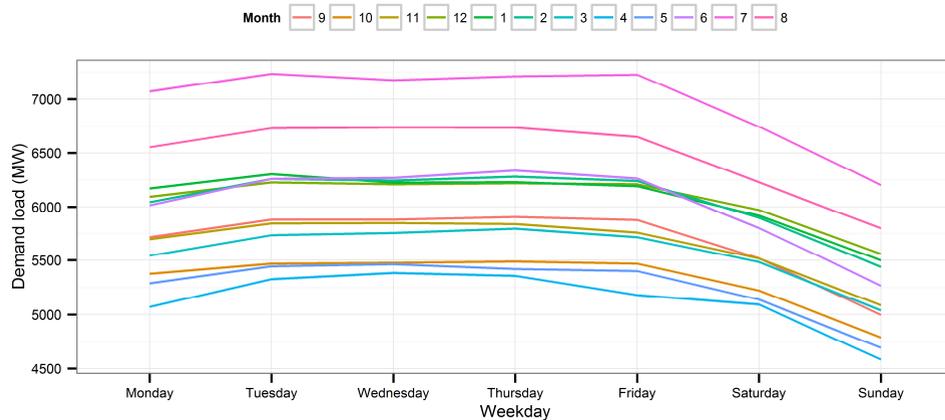
# 4. Daily and weekly behaviour of the demand load

## Distribution of the demand load during the day



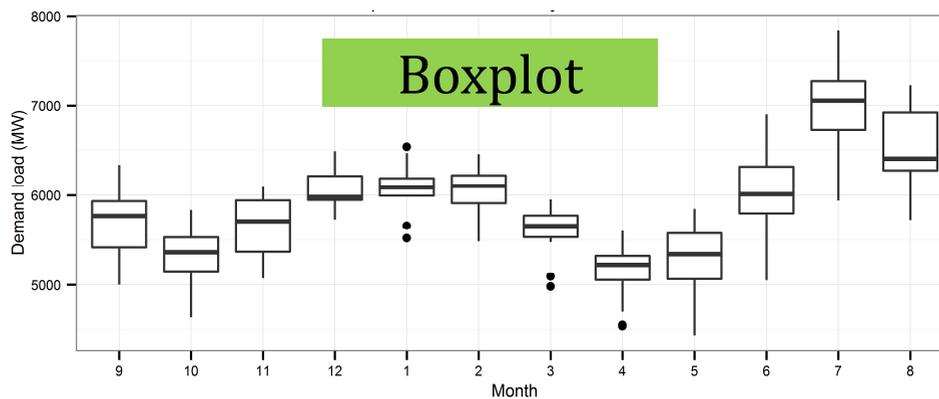
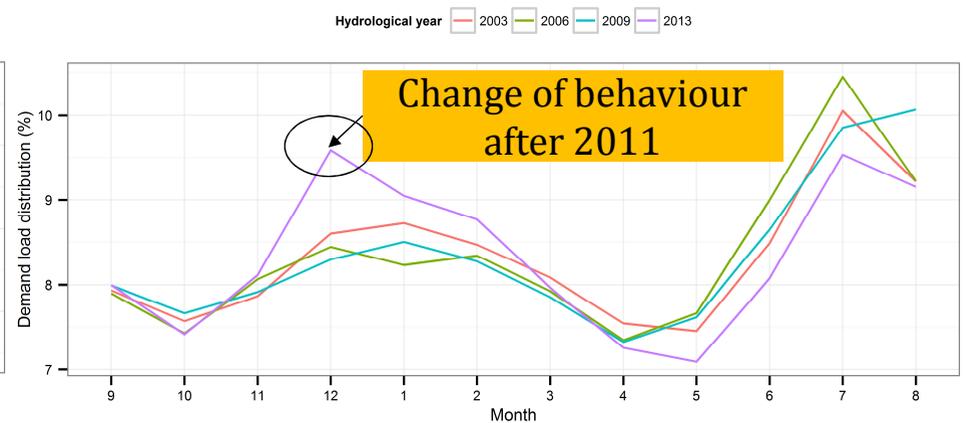
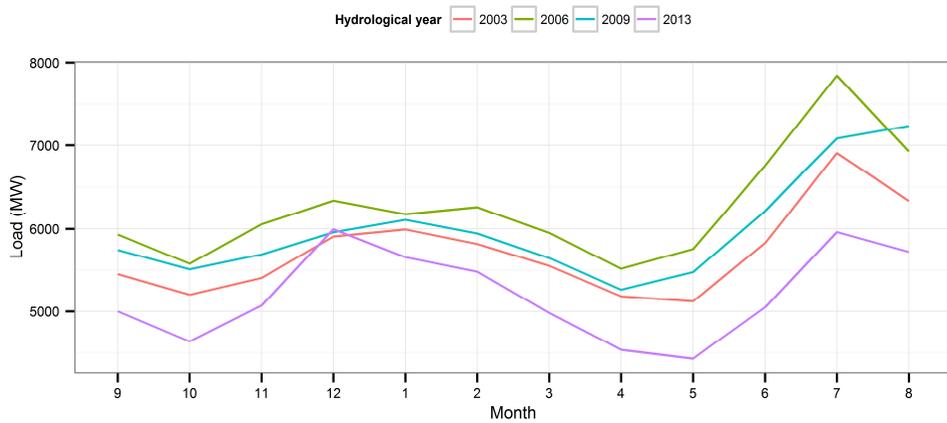
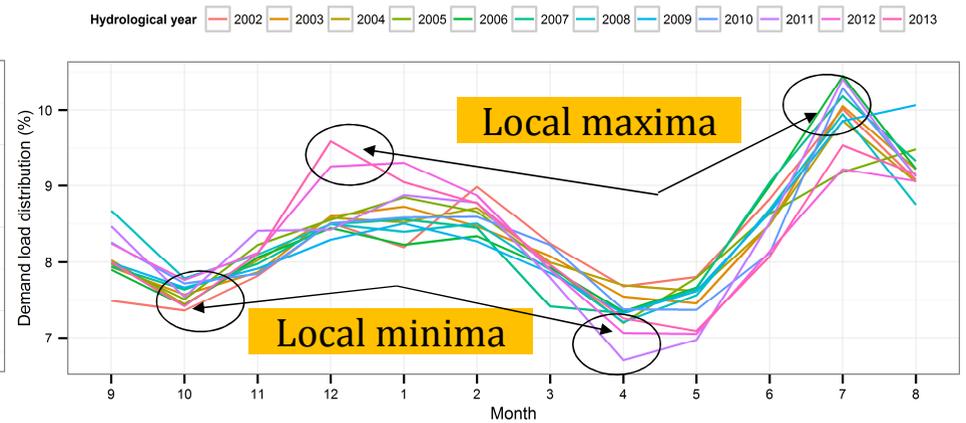
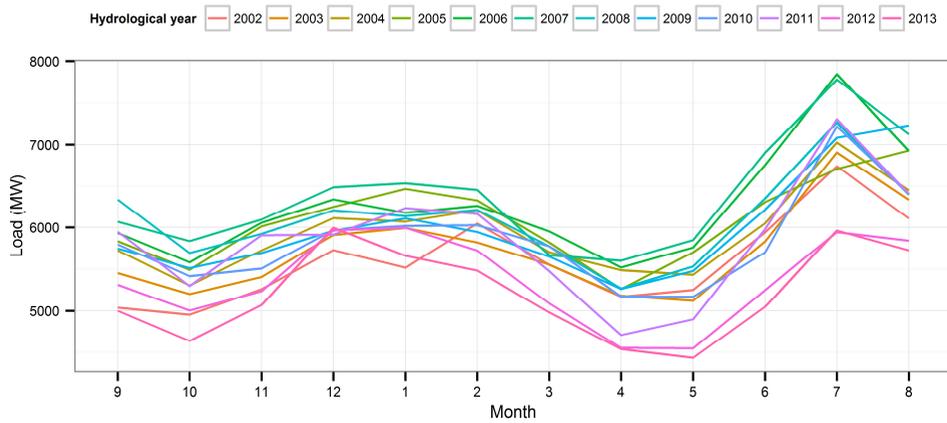
## Distribution of the demand load during the week

The shape of the demand load is almost independent of the month



# 5. Monthly behaviour of the demand load

## Distribution of the demand load during the year

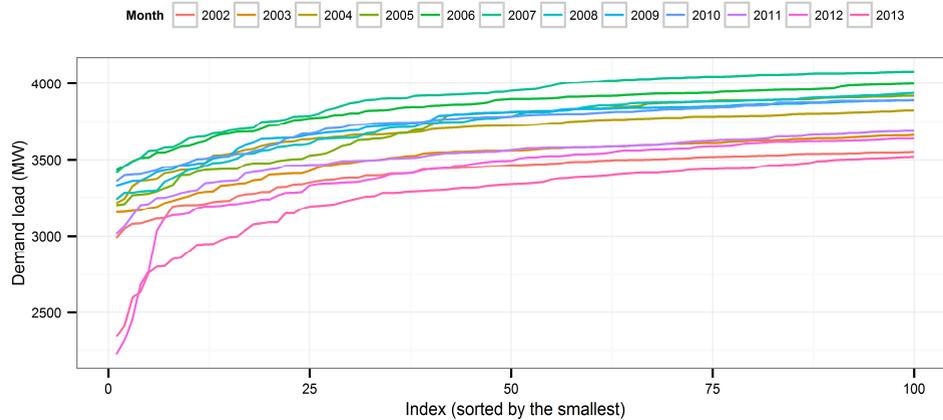


Smaller variations from December to April

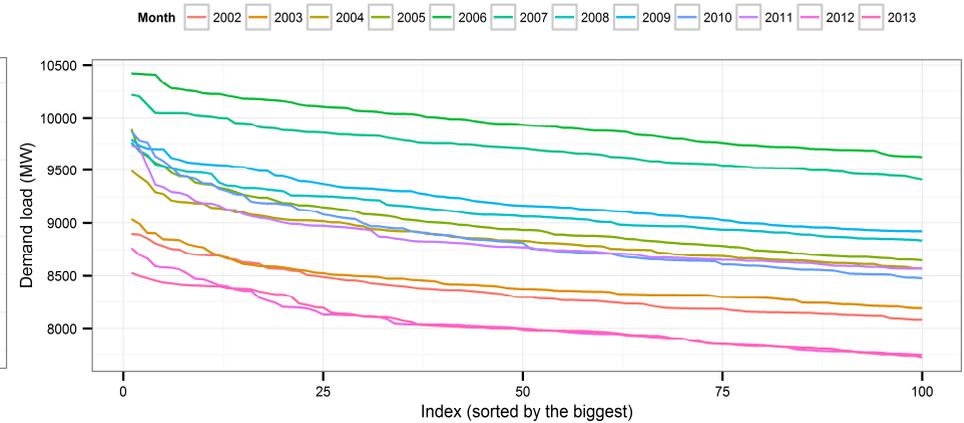
Hydrological year  $x$  is defined in this study as time period September of  $x$  – August of  $x+1$ , where  $x$  denotes calendar year

# 6. Extreme values and the New Year's Eve

## 100 smallest hourly values per year



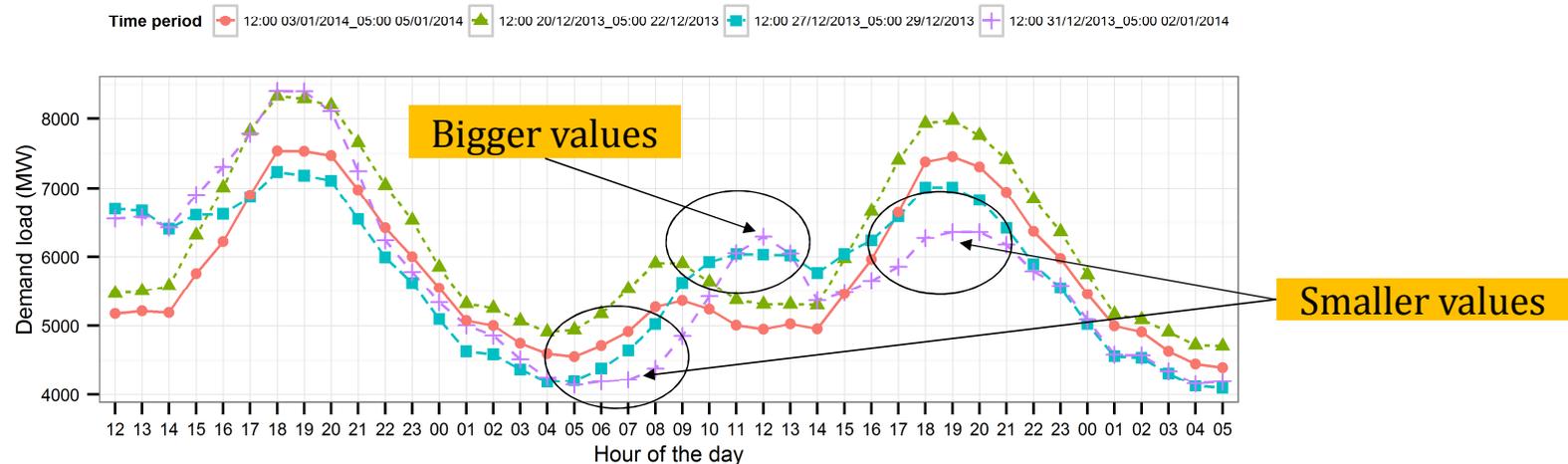
## 100 biggest hourly values per year



## What happened the New Year's Eve?

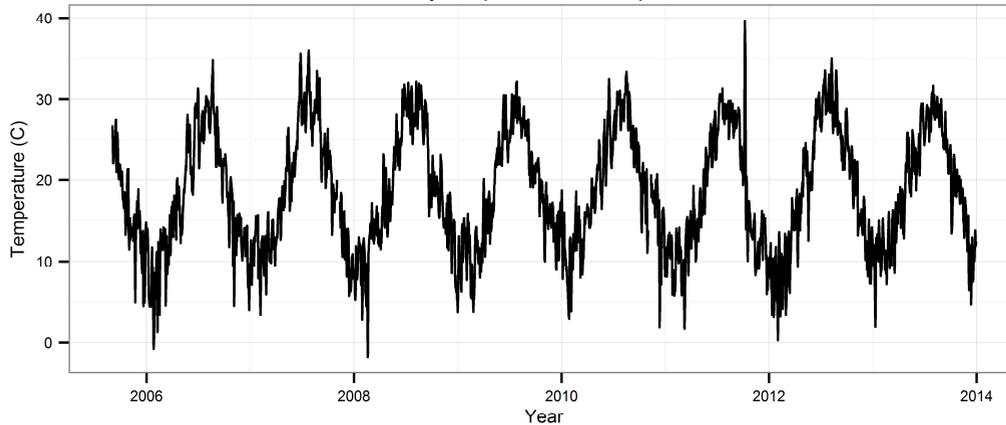
The January 1<sup>st</sup> of 2014 is compared with the weekends before and after

What happened in 2014-01-01

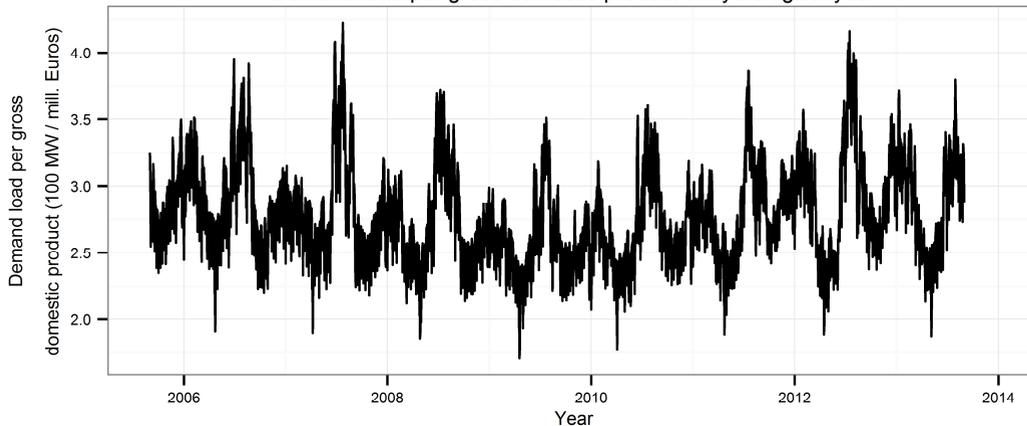


# 7. Demand load, temperature and GDP

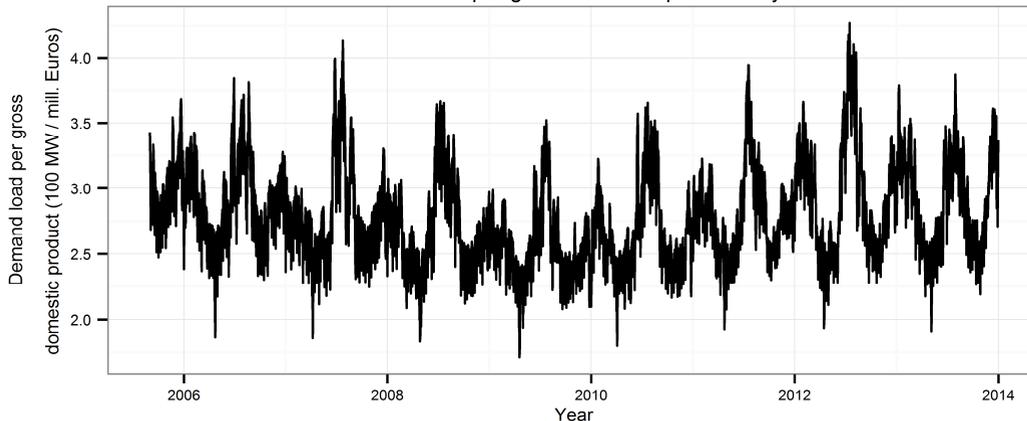
Mean daily temperature at Ilioupolis station



Demand load per gross domestic product of hydrological year



Demand load per gross domestic product of year



The temperature measured at the Ilioupolis station will be used in the analysis.

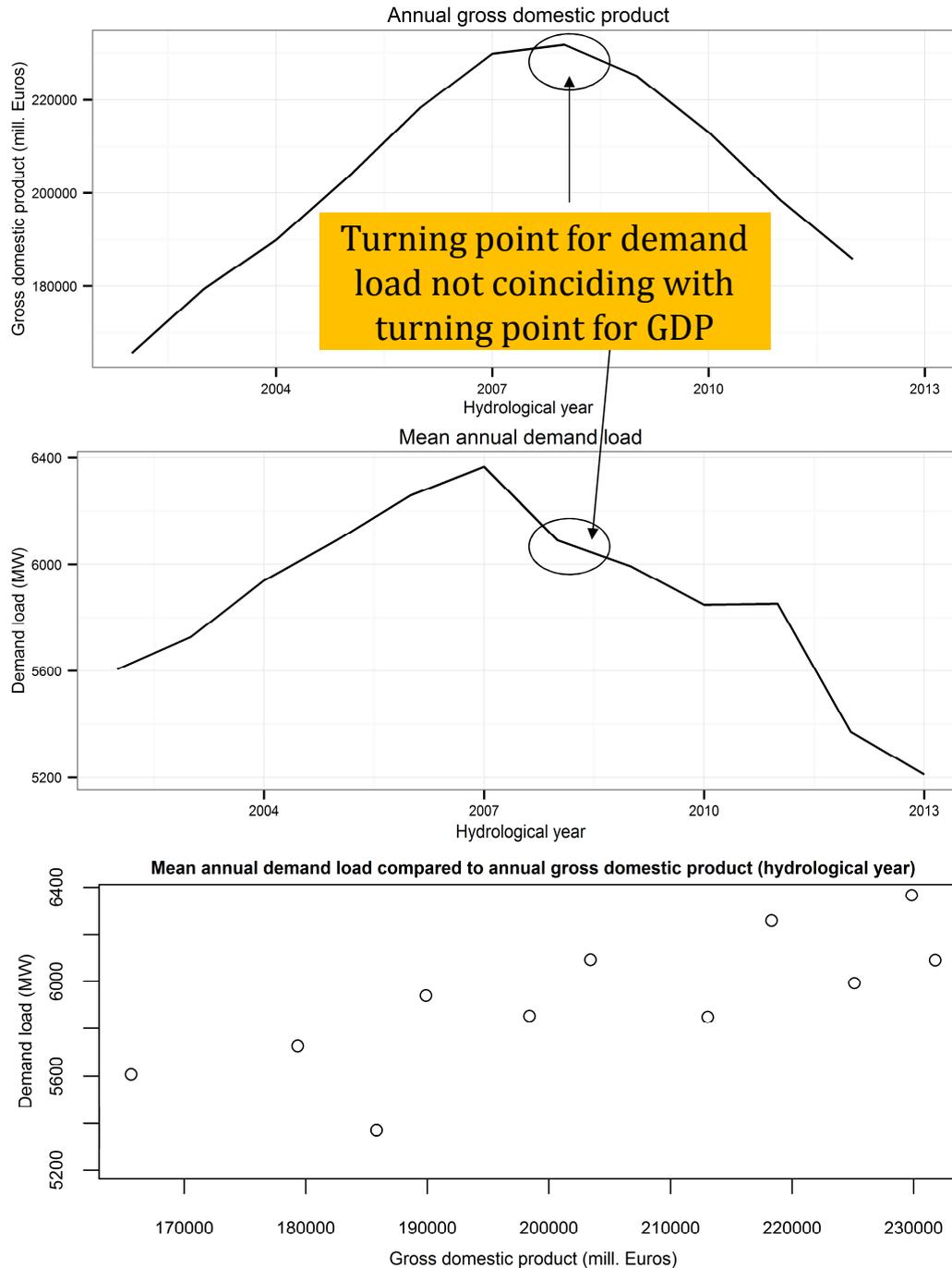
- Ilioupolis is in Athens, which is inhabited by 35% of the population of Greece.
- It is near the sea, thus it is less sensitive to extreme weather events



Demand load per Gross Domestic Product (GDP) will be used to find the relation between demand load and temperature. The reason is that the demand load is usually modelled linearly with the GDP.

Temperature data source: The Hydrological Observatory of Athens (2015)  
Gross Domestic Product data source: The World Bank (2015)

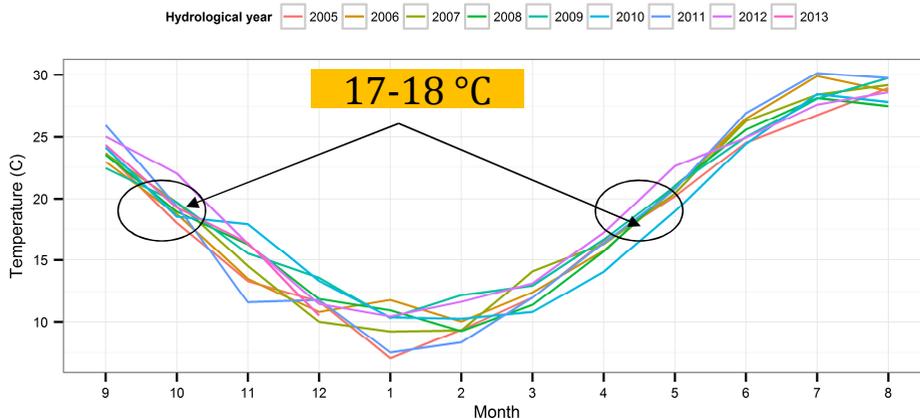
# 8. Demand load and GDP



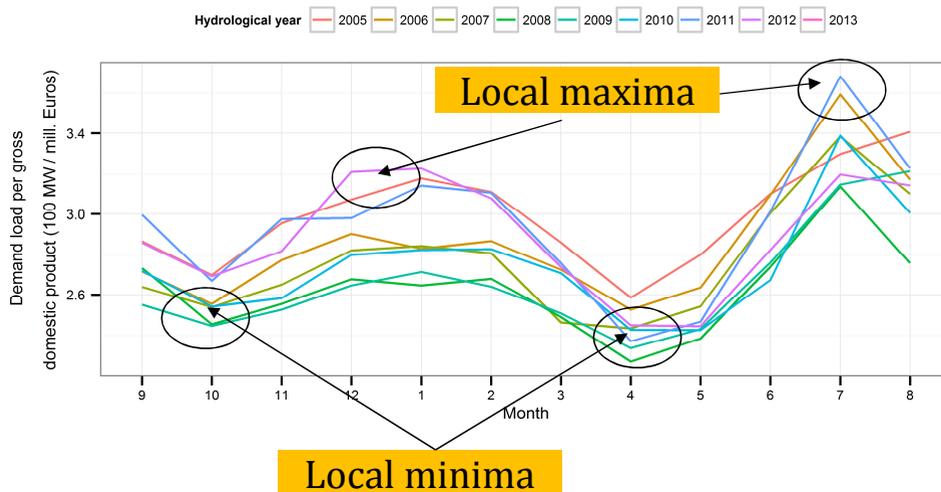
- Increase of the GDP is followed with increase of the demand load
- However the hydrological year 2008, the slight increase of the GDP was followed with a major decrease of the demand load
- Thus it seems that more economic indexes are needed to model the demand load
- In the bottom figure it is shown that a linear model of the relation between the GDP and the demand load seems justifiable

# 9. Demand load and temperature

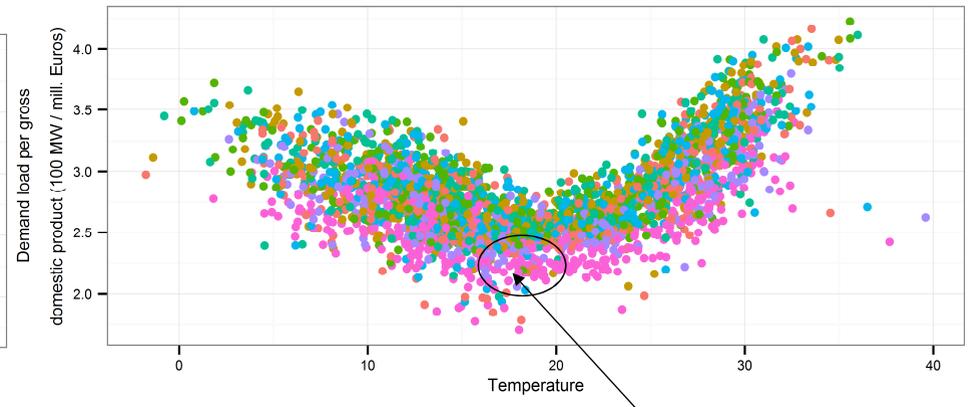
Monthly mean temperature by hydrological year



Monthly mean demand load per gross domestic product of hydrological year

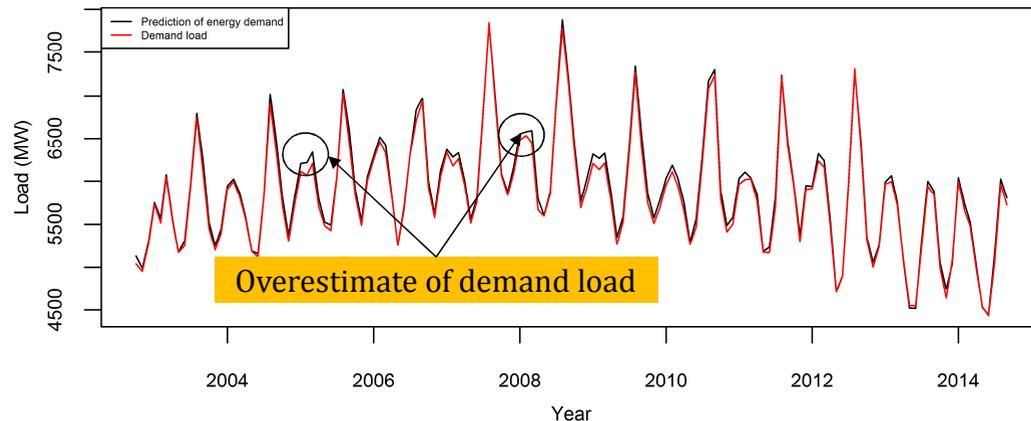
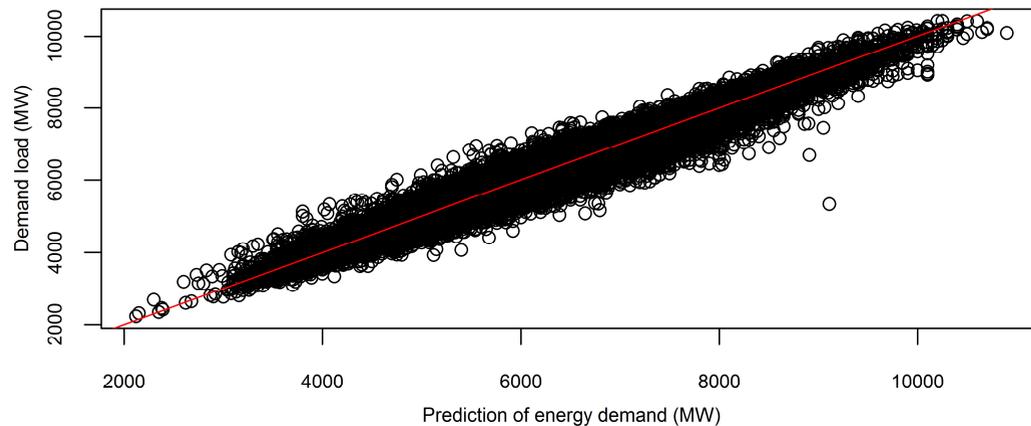
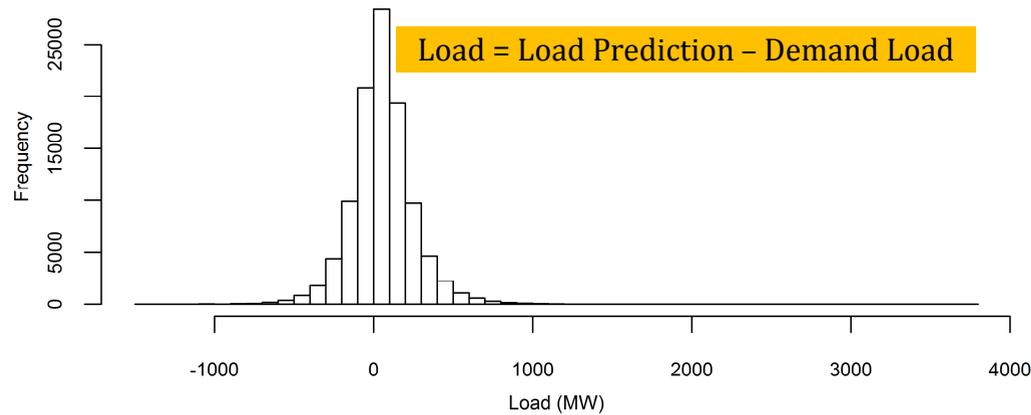


Weekday: Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday



- For smaller or bigger temperatures, we observe an increase of the demand load (see top right and bottom left figures)
- Smaller temperatures correspond to winter months and bigger temperatures correspond to summer months
- A global minimum for the demand load is observed for temperatures around 17-18 °C
- Temperatures around 17-18 °C are observed the spring and autumn months (see top left figure)

# 10. Demand load and load prediction



- The Independent Power Transmission Operator predicts the demand load for the next day
- It seems that the prediction is an overestimate of the demand load. The histogram of the top figure is asymmetric to the right
- This is also confirmed from the middle figure, with more values under the red line
- The bottom figure shows an overestimate of the demand load for the winter months

# 11. Conclusions

- Global hourly maximum during the day around 20:00 and another local maximum around 12:00. Local minima around 04:00 and 16:00.
- Maxima of the daily demand load are observed on Wednesdays or Thursdays and minimum of the demand load is observed on Sundays.
- The shape of the daily demand load is almost independent of the month.
- Local maxima of the monthly demand load are observed in January and July and local minima of the demand load are observed in October and April.
- After the hydrological year 2011 the monthly demand load in December was increased considerably.
- Smaller variations of the monthly demand load are observed from December to April.
- A linear model of the relation between the GDP and the demand load seems justifiable. Furthermore an increase of the GDP usually results in an increase of the demand load (or vice versa?).
- However the hydrological year 2008 the increase of the GDP was not followed by an increase of the demand load.
- A global minimum for the hourly demand loads is observed for temperatures around 17-18 °C.
- Local maxima of the demand load are observed for the temperatures around 3 °C and around 32 °C.
- A regression line for the demand load (in the y axis) and the temperature (in the x axis) would be convex.
- The Independent Power Transmission Operator's daily predictions usually overestimate the demand load.

# References

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