ecoheatcool
A EUROHEAT & POWER INITIATIVE

Supported by
Intelligent Energy Europe

ECOHEATCOOL
Work package 2

The European Cold Market

Final Report

This report is published by Euroheat & Power whose aim is to inform about district heating and cooling as efficient and environmentally benign energy solutions that make use of resources that otherwise would be wasted, delivering reliable and comfortable heating and cooling in return.

This report is the report of Ecoheatcool Work Package 2

The project is co-financed by EU Intelligent Energy Europe Programme. The project time schedule is January 2005-December 2006.

Up-to-date information about Euroheat & Power can be found on the internet at www.euroheat.org

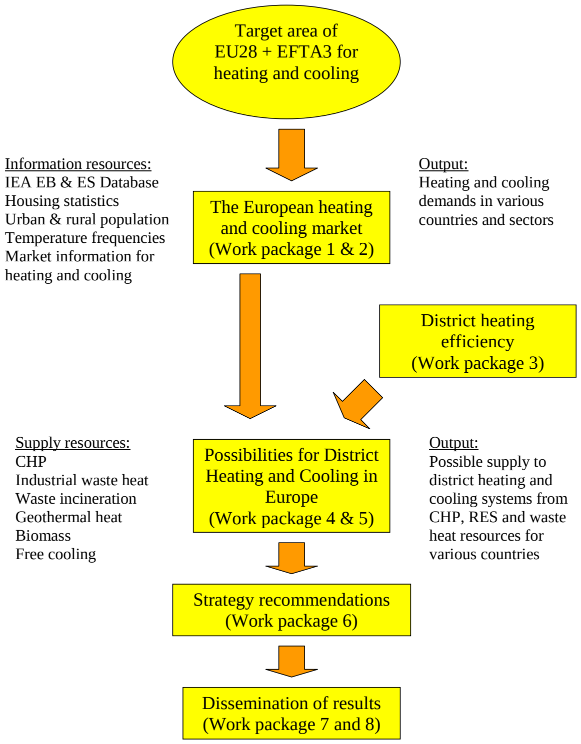
More information on Ecoheatcool project is available at www.ecoheatcool.org

Euroheat & Power
Avenue de Tervuren 300,
1150 Brussels
Belgium
Tel. +32 (0)2 740 21 10
Fax. +32 (0)2 740 21 19

Produced in the European Union

ECOHEATCOOL

The ECOHEATCOOL project structure



Project co-ordinator: **Norela Constantinescu,** Euroheat & Power,

norela.constantinescu@euroheat.org

This report is the main report for work package 2

Principal authors: are Pär Dalin, Joakim Nilsson and Anders Rubenhag, Capital Cooling Europe AB, Sweden

With the contribution by:

Euroheat & Power

Danish District Heating Association, Demark,

Finish Energy Association, Finland

German District Heating Association, Germany

Italian District Heating Association, Italy

Austrian Association of Gas and District Heat Supply Companies, Austria

Swedish District Heating Association, Sweden

Norwegian District Heating Association, Norway

Confederation of European Waste to Energy Plants, Belgium

Czech District Heating Association Czech Republic

Contents

1 Executive summary

The main purpose with this report from the second work package of the ECOHEATCOOL project is to present an overall definition and description of the European cooling market and its potential growth. The target area is 32 countries, including the EU25 community, the four accession countries, and three EFTA countries. The definition of the European cooling market is the important foundation for the quantification of the benefits of an expanded use of district cooling in Europe that will be performed in the fifth work package of the ECOHEATCOOL project.

The cooling demand analysis has been co-ordinated with the ECOHEATCOOL Work Package 1 - heat market study.. It is therefore recommended to use that report as background information to this report. In comparison to the heat market there are some major differences that make estimations and predictions for cooling market more complex:

- Cooling is a relatively new and rapidly expanding market
- Electricity use for cooling is embedded in the buildings total electricity consumption. The usage is divided on several electricity consumption equipments and are very seldom monitored on an aggregated level
- Broad variations in technical solutions, design guidelines and operational strategies exist
- A large proportion of the total cooling demand is due to non climatic conditions which implies a wide variation of full load hours within the same geographical region.
- So far district cooling has limited market share with only 1-2% of the total cooling market within the service sector. Moreover aggregated benchmarking figures are not systematically collected.

Focus in this report was placed on finding the methods to determine the total potential cooling demand within Europe and to make estimations for the total potential and the potential market saturation and its impact on the European energy balance.

A new European Cooling Index (ECI) has been invented and introduced in order to explain the geographical distribution of the average specific space cooling demands in Europe.

The total potential cooling demand in Europe (EU-32), if 100% of all useful space would be air conditioned, is estimated to an annual 1400 TWh_c

All information sources analysed show that a strong market expansion has taken place during the last decade. The forecasts predict the same pace rate of development. The growth is mainly due to the fact that the standard of living has made this type of equipment affordable. At the same time t peoples comfort standard requirements have increased. Market experience also shows that once 20% of the office space in a city is air conditioned it sets the rental value and un-cooled space only can be let at discount.

With a saturation rate of 60% for the service sector and 40% for the residential sector " the European saturation rate" the cooling market will show a four fold increase between 2000 and 2018, corresponding to 500 TWh_c for the EU-15. This is about 200 TWh_c higher that earlier predictions (EECCAC,2003). For all 32 countries this would correspond to 660 TWh_c, Another faster expansion scenario based on the expansion rate during 2004 indicates that the "the European saturation rate" could be reached already by 2012.

Major unknown factors are:

- Building statistics for the service sector,
- Aggregated specific cooling demands,
- Bench mark figures for location above the ECI-100 level,
- The present market saturation
- EU electrical statistics which are not enough detailed and not divided by sectors.

More detailed national studies of these parameters would contribute to a better understanding of the cooling market.

The major conclusions from this study are:

- The potential cooling demand and the pace of expansion for the European cooling market are greater than earlier indications
- The impact from the forecasted demand, using conventional, low efficient cooling equipment put pressure on electricity capacity and demand. This will hinder the European commitments regarding CO2 savings, will increase the electricity prices and drive the need for capacity investments (Peak demands put pressure on power capacity both in production and transmission)
- The need to improve understanding on how power demand is driven by consumers needs and their changing behaviour patterns is of great importance
- The need to understand how the cooling needs is met by an increased electricity demand.. The new directives focusing on energy efficiency in buildings might bring more light on the actual energy demands for running this type of systems
- This study give further evidence that a fast and wide implementation of energy efficient District Cooling has a major role to play in order to meet the challenges for Europe, in order to provide a robust and environmentally sound framework for future energy solutions

2 Introduction

2.1 *Background*

The demand for comfort cooling is steadily increasing in all European countries, both old and new EU Member States as well as in the Accession Countries.

At present the use of energy for comfort cooling is to a high degree unknown on an aggregated EU level. This is mainly due to that it is not specifically monitored on building level. Key-figures and bench mark information are often well documented for heating but for cooling these figures are embedded in the total electricity usage for a building. Since the estimation of electricity use is also built up from various sources such as chillers, auxiliary equipment and also ventilation systems it is a complex task to monitor and to allocate the right amount to the right source.

The present lack of information for demands and supply at national and European level needs a more structural approach to provide comprehensive, aggregate information about the cooling market and its dynamics in Europe.

At the same time it is important to create tools for assessing and monitoring the cooling market which develops fast.

A consistent approach and the creation of a cooling market framework will enable the identification of areas of actions and political instruments at European, national and local level.

The market sectors where cooling demand has been analysed can be defined as:

- Residential = public and private community accommodation (i.e. private housing, flats, student accommodation etc.)
- Service sector = public buildings (health care, education, administration buildings etc) plus commercial sector (retail, office, hotel, leisure etc)

As defined in chapter 2.3 industrial buildings and process cooling is not covered in this report.

2.2 *Objectives*

The objective of this report is to make first analysis of the comfort cooling demands in buildings in Europe.. The results should give comprehensive, aggregated information about the cooling market and its dynamics in Europe. This report will form the foundation for estimating the implications from establishing new district cooling systems in the succeeding report within the ECOHEATCOOL project. This next report will focus on the possibilities and potential of district cooling and its implications on higher security of supply, higher energy efficiency, carbon dioxide reductions and the impact on the power grids.

2.3 Scope of work

The cooling demands covered in this study are demands for cooling in service end residential buildings, i.e. cooling demands triggered by climatic conditions, heat load from office machinery etc.

Excluded in this study are:

- Cooling demands within the industry sector
- Process cooling demands within the studied sectors such as low temperature cooling (<+4 degrees) for food handling etc.
- The target area for this heat market study is 32 European countries. These countries are:
- The current EU25, divided into two sub-groups: the former EU15 before May 2004 and NMS10, the ten new member states from the enlargement in May 2004
- The four accession countries in the ACC4 group (Bulgaria, Romania, Turkey, and Croatia)
- The EFTA countries in the EFTA3 group (Iceland, Norway and Switzerland).

Where appropriate, these groups will be used:

Table 1. The 32 countries examined divided into to four different groups.

EU15	EFTA	EU+10	EU ACC
Austria	Iceland	Cyprus	Romania
Belgium	Norway	Czech Republic	Bulgaria
Denmark	Switzerland	Estonia	Croatia
Finland		Hungary	Turkey
France		Latvia	
Germany		Lithuania	
Greece		Malta	
Ireland		Poland	
Italy		Slovak Republic	
Luxembourg		Slovenia	
Netherlands			
Portugal			
Spain			
Sweden			
United Kingdom			

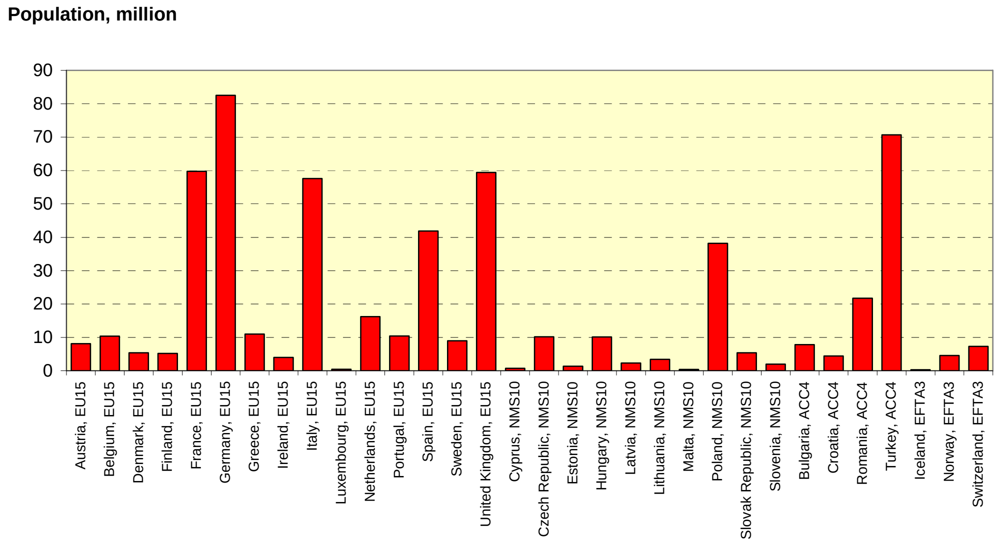


Figure 1. Average population during 2003 in the 32 countries. Source: (Eurostat online database 2005)

2.4 Methodology

The methodology used implied gathering information by country on:

- Frequencies for outdoor temperatures
- National electricity demand variations
- Specific market information from international databases, international statistical reports and commercial market reports.

For comparisons and estimations of cooling demands on different locations in Europe a new Europe Cooling Index for has been developed.

The assessment of cooling demands involves the use and crosschecking of elements such as:

- Cooling demand profile
- A new cooling index
- Specific cooling demands for residential and service buildings
- Building stock statistics
- Electricity demands
- Estimations from market reports regarding equipment sales

The assessment of the cooling market covers aspects such as market description, equipment and cooling suppliers and indications of cooling costs and prices.

3 Cooling demands

Cooling demands for comfort purpose in buildings are mainly due to climatic conditions. Other important factors are technical installations, building standards and social behaviour.

Cooling demands and climate considerations in buildings can be analysed by considering a number of specific conditions:

- Regional climatic conditions: the temperature and humidity differences depending on geographical position.
- Urban climatic conditions - the climate in densely built areas can differ from surroundings climate as for example the temperature, wind speed, and humidity.
- Building climatology that analyses human thermal comfort and the effect of architectural and structural design features including layout, insulation, window orientation, and shading, and ventilation conditions on the indoor climate.
- The design and operation strategy (seasonal and day/night) of the cooling supply installations.
- Furthermore internal heat generation from people, lighting, printers, computers and other machines adds up to define the actual cooling demands.
- Social behaviour: normal working hours, vacation periods and required indoor temperature etc also have a major impact on the timing of the cooling demands of buildings whether they are for service or residential use.
-

3.1 Climatic conditions

Climatic conditions with an impact on cooling demands are temperature, wind, solar radiation and air humidity. The predominating factor of these is normally the out door temperature. A more detailed analysis of these climatic factors is to be found below where the new cooling index is presented and explained. Outdoor temperature conditions differ widely in Europe. During the summer months the average temperatures may differ 10 to 15°C between European capitals. A few examples are displayed Figure 2 below.

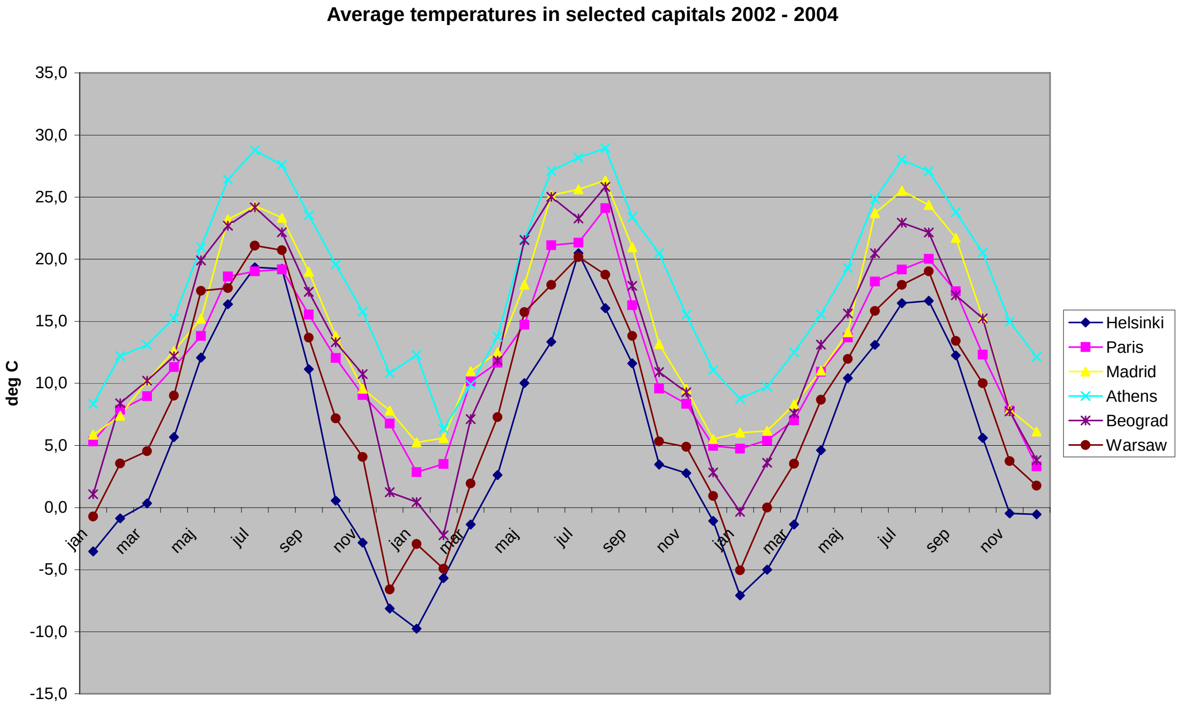


Figure 2 Average temperatures in selected capitals 2002-2004

3.2 Cooling index

In the same way as for the new European heating index (EHI, ECOHEATCOOL, WP1 2005), a new European cooling index has been constructed based on the same principles. First, it is assumed that the outdoor temperature is the predominating factor for the heating and cooling demand. Further more it is assumed that the heating demand (and not the cooling demand) is the predominating factor for building insulation. Therefore the same approach as for the EHI has been used. The optimal insulation thickness is proportional to the square root of the heating degree-day number, by assuming a certain heat cost and certain insulation cost. Also recovery of heat from ventilation systems would follow the same relationship. Hence, the cooling use depends on both the cooling degree-day number and the heating degree-day number, since the overall building heat resistance should be proportional to the square root of the heating degree-day number.

The new European cooling index (ECI) has been constructed according to the analysis above and is presented in Figure 3 . The index is normalised, where 100 is equal to an average European condition, which occur in for example Strasbourg and Frankfurt, where the average outdoor temperature is just above 10ºC, see Figure 4 . The solar and internal gains are also adjusted by the square root of the heating degree-day number, since these gains are more valuable in temperature addition, when a building is well insulated.

In the construction of the ECI it is also assumed that the cooling systems are designed to maintain an indoor temperature of 22°C only when the outdoor temperature is below 29°C. When the outdoor temperature exceeds this limit, the indoor temperature will start to slide at a constant difference of 7°C below the outdoor temperature.

Humidity has not been included in the index even though it contributes to the cooling demand in two ways. First, humid air has a higher specific heat capacity (c_p) than dry air, which means it takes more energy to increase or decrease the temperature of humid air 1 °C than it would take for dry air. Secondly, when humid air is cooled down to the required indoor temperature the dew point may be passed, which means that a part of the humidity will condense.

The difference in c_p between dry and humid air is very small (~2%) in the relevant interval, and is therefore considered as negligible. In the cases where the dew point has to be passed to reach the required indoor temperature the condensation energy makes a significant contribution to the cooling demand. The impact of this is however depending on the types of air conditioning systems that are used and also what design criteria that are used. A sliding indoor temperature as assumed in the construction of the index will limit the impact of humidity compared to a system where the indoor temperature is fixed, regardless of the outdoor temperature.

Other used simplifications for the new cooling index are the constant energy supply in the solar gain used and no adjustments for different human metabolism and electricity indoor use in various countries. Eliminating these simplifications can of course refine the index, but it should be a pedagogic value to keep it simple.

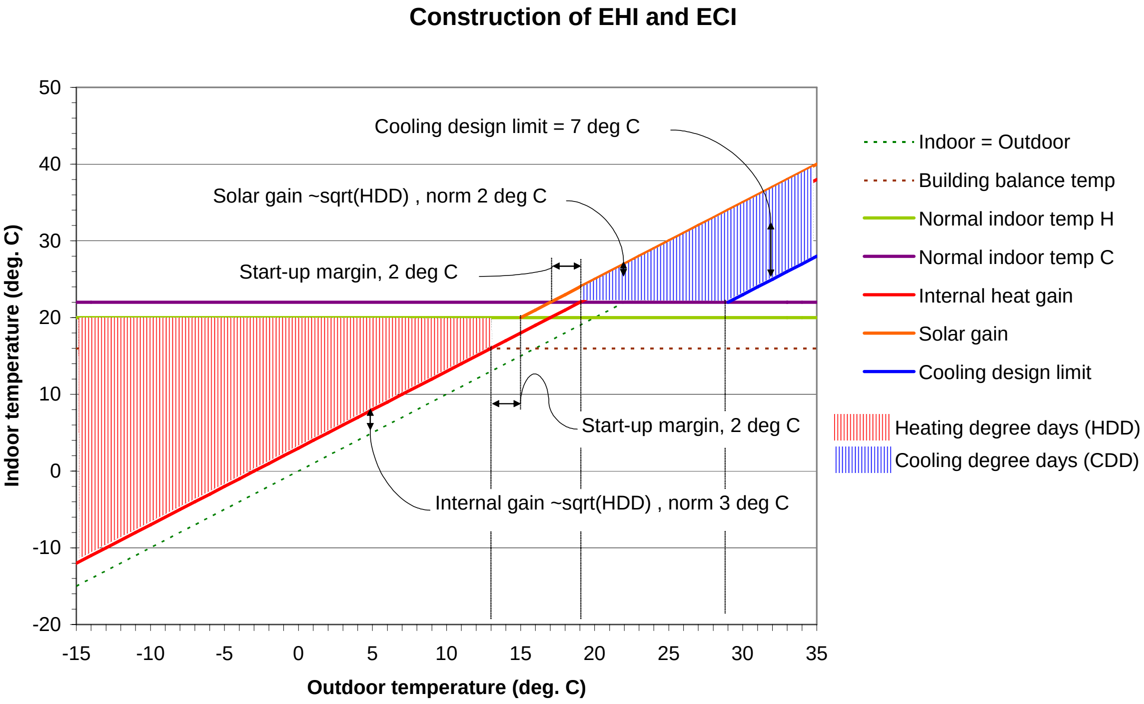


Figure 3 Construction of European heating and cooling index

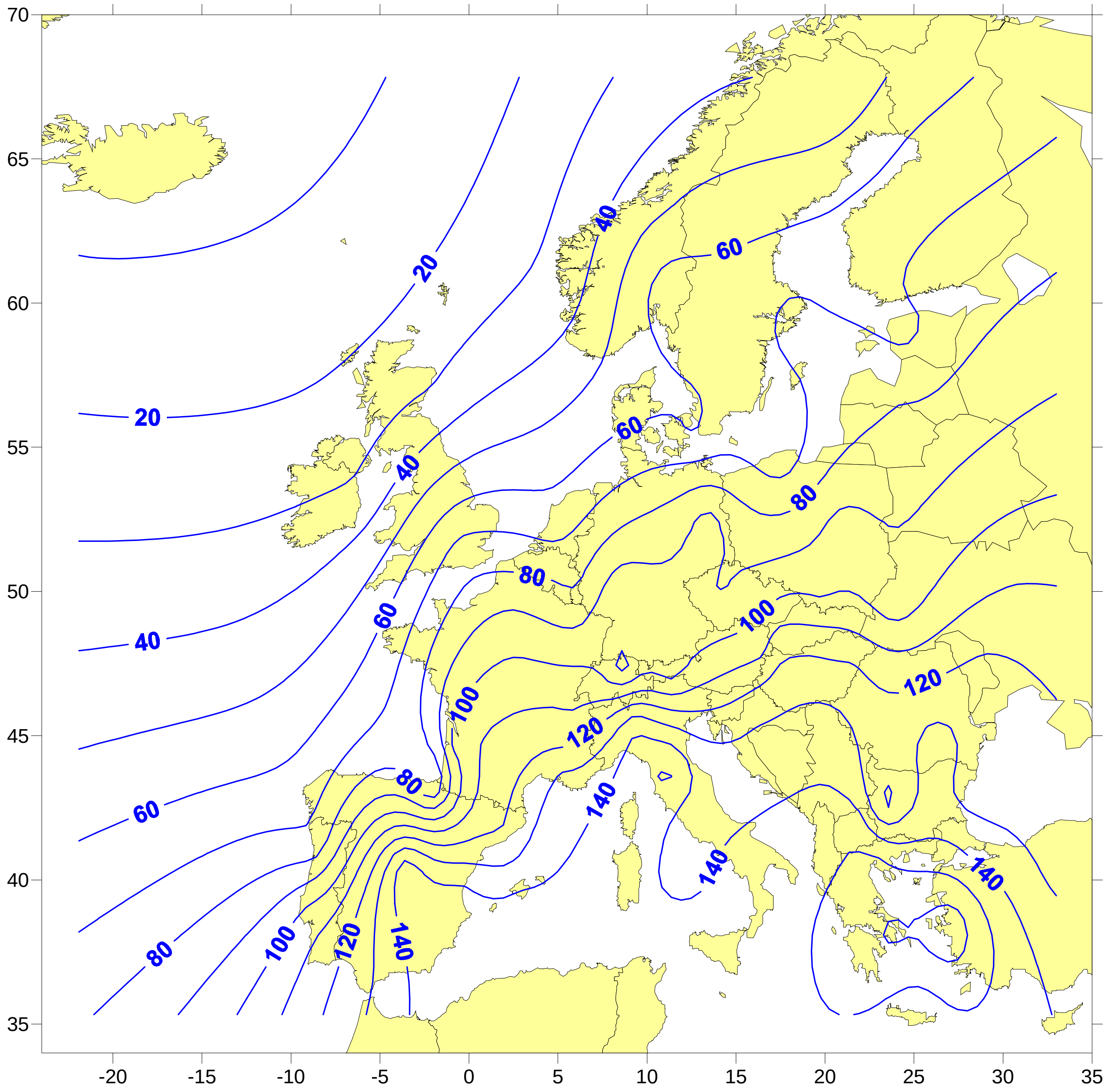


Figure 4 European cooling index (ECI) in a contour map computed from information from 80 urban locations in Europe. The average space cooling demand should be proportional to this index. Note that the map is not representative for all locations in each country, since the existing data grid consists of only 80 locations.

3.3 Specific demands

Data regarding annual specific cooling demands in terms of kWh/m^2 gives a scattered picture depending on the source that is consulted. This may be due to different ways to define the building areas, use of buildings and climate, but also to the fact that the cooling standard may vary widely between different buildings within a building population. According to a real estate handbook (Repab Fakta, 2001) the demand may differ by a factor 3 between different office buildings with identical outer conditions, depending on the cooling/ comfort standard of the buildings. This or even a larger spread is confirmed in interviews with energy companies running district cooling. For traditional building with traditional air conditioning equipment , should be mentioned the poor awareness regarding the actual energy usage for cooling, due to the fact that electricity consumption is embedded in the buildings total electricity consumptions. This , implies that specific key-figures are not collected on an aggregated level.

In the Nordic countries public and office buildings are normally dimensioned for a specific cooling load of 30-60 W/m^2, while retail areas are dimensioned for 50-80 W/m^2. Duration times are usually within the range of 1100-1300 equivalent full load hours per year. For the south part of EU the specific cooling load is about 20% higher and the duration time up to 50% higher. (DEA, 2005)

For residential buildings the specific cooling load demand is lower due to less internal heat generation and lower duration times the tenants are not being home during hours when cooling needs are highest. Dimensioning load is about 20 to30% lower and duration time up to 50% lower than for the service sector (DEA, 2005 and RAC, 1999).

3.4 Building stock

The same building stock analysis is used for work package 1 and 2 (WP1&2). For more information see (ECOHEATCOOL, WP1, 2005).

3.4.1 Residential buildings

The total useful floor spaces in residential buildings in various countries are available from the annual publications of “Bulletin of Housing Statistics for Europe and North America” (UNECE, 2005) and “Housing Statistics in the European Union” (Boverket, 2005). This gives a possibility to easily gather the current use of residential buildings in the target area.

National average residential useful floor space per capita is presented in Figure 5 versus each national GDP per capita. The diagram reveals that the use of residential floor space increases with the national GDP, but is not directly proportional. The relationship is more like that the residential areas is proportional to the square root of the GDP. Residential living is a basic social demand that must be met. The population in richer countries do not spend all their money for getting more residential space. They prefer also other ways of spending money.

The average use of residential space was 36, 5 m^2 per capita in the whole target area, while the total number of dwellings was 240, 3 million, having a total floor area of 20, 9 million m^2. The corresponding information is presented in Table 2.

Table 2. Residential information per country group during 2003.

Country group	Number of dwellings, millions	Total residential floor area, billion m^2	Residential floor area per capita, m^2
EU15	178,4	16,0	41,9
NMS10	26,2	1,9	25,5
ACC4	29,9	2,4	23,3
EFTA3	5,7	0,6	45,2
Total	240,3	20,9	36,5

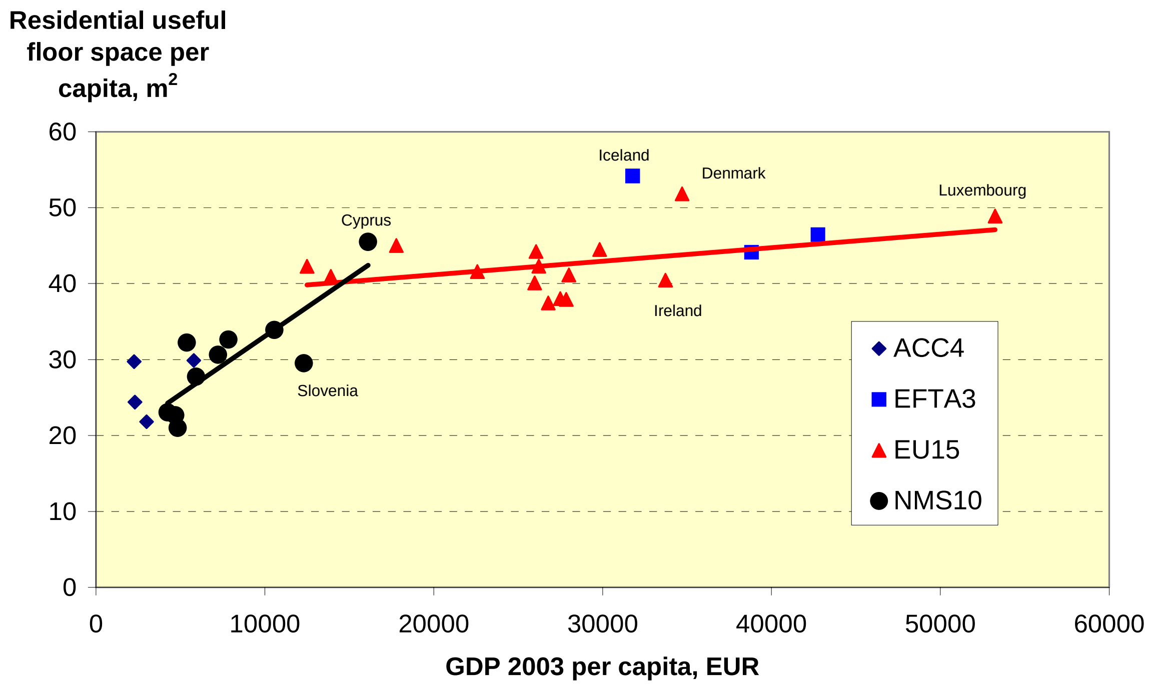


Figure 5. Residential useful floor space per capita versus each national GDP per capita for 2003. Average lines added for the EU15 and NMS10 country groups.

3.4.2 Service buildings

Many countries do not gather information on the size and structure of the service sector buildings. This lack of data availability makes a strong contrast to residential information, with higher social and political dimension. Also the Eurostat, 2002 report regarding service sector energy consumption lacks relevant information about the useful floor area in the service sector.

Statistical national values for floor areas in the service sector have been gathered for 20 of the 32 countries. The 12 countries with missing information are Austria, Belgium, Ireland, Luxembourg, Estonia, Latvia, Poland, Hungary, Malta, Cyprus, Bulgaria, and Romania, representing 18 % of the population in the target area. When specific use is later estimated in the report, the weighted average floor area for each country group has been used to estimate the missing national areas. These averages were 14, 6 m^2 for EU15, 10, 0 m^2 for NMS10, and 4, 0 m^2 for ACC4.

Each identified national average service sector useful floor space per capita is presented in Figure 6 versus each national GDP per capita. The variation within the country groups is now more pronounced compared to the corresponding residential information in Figure 5. Especially Netherlands, Italy, and Spain have much less service sector areas than other EU15 countries. It is more difficult to find an obvious relationship between service sector area and GDP. It appears that countries with fully developed service sectors including a strong public sector have a service sector area per capita of about 20 m^2, as for Germany, Switzerland, and the five Nordic countries.

Including estimates for missing countries, the total service sector area is 7, 0 billion m^2, giving an overall average of 12, 2 m^2 per capita.

A European average composition of service sector buildings is: 12 % for hotels and restaurants, 13 % for health and social buildings, 18 % for education and research, 26 % for offices and public administration, 22 % for commercial purposes, and finally 10 % for other purposes. This average composition was based on information from 16 countries gathered for this project.

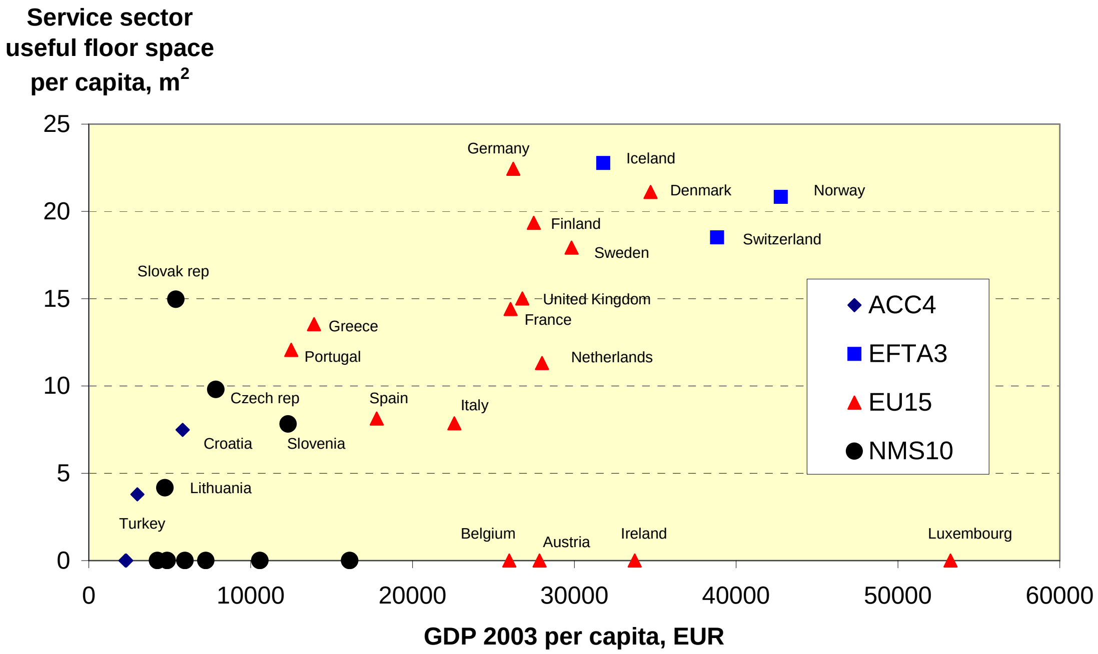


Figure 6. Useful floor space in the service sector per capita versus each national GDP per capita for 2003.

3.5 Total potential cooling demand for buildings

The estimation of potential cooling demand in Europe was carried out by using the specific cooling demands, cooling index and building areas for residential, service buildings as described above.

The analysis has been performed in three steps:

1. First the specific demand information from Paris, Prague, Stockholm, Oslo, Helsinki and Amsterdam are compared to the cooling index for each capital. The analysis shows a fair correlation of +/-5% and the European Cooling Index at level 100 (ECI-100) is 82 kWh/m^2 for the service sector, and 37 kWh/m^2 for residential buildings
2. Secondly the demands have then been extrapolated to the capitals of all the countries in the study by using their cooling index.
3. Finally the total potential for each country has been calculated by multiplying the extrapolated specific demand with the total building stock areas of the countries. The result of this estimation is that the European cooling potential for the total useful building stock is 1370 TWh$_c$ per year or 560 TWh$_c$ for the service sector and 810 TWh$_c$ for the residential sector.

The cooling potential per country is illustrated in Figure 7.

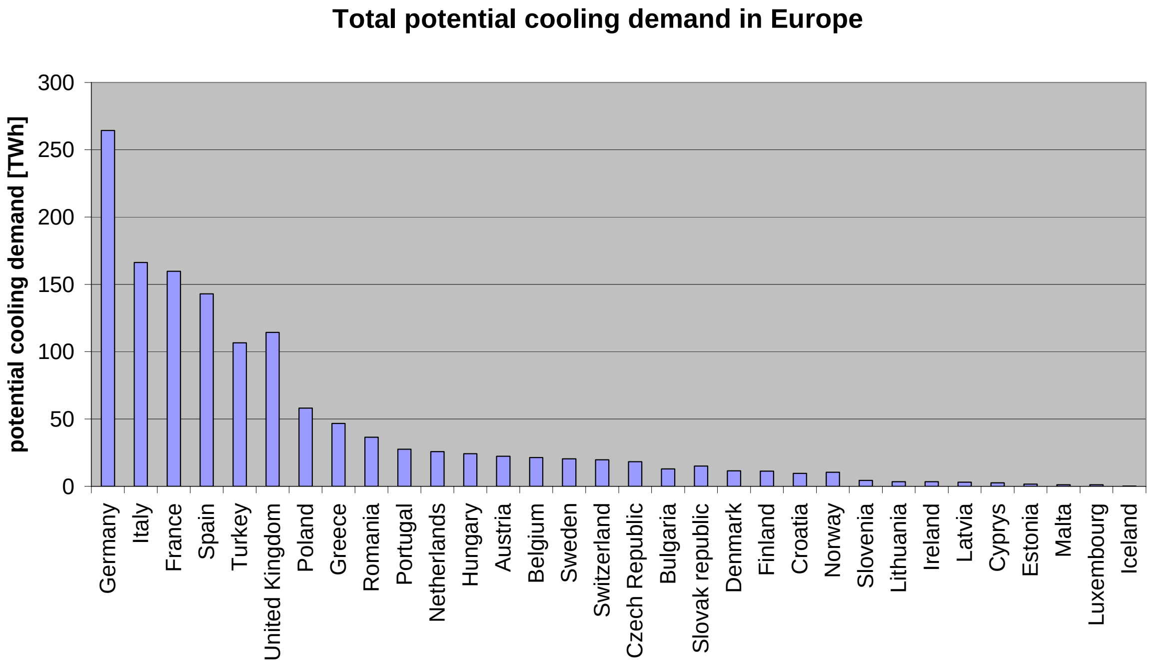


Figure 7. The Potential Cooling demand in buildings for 32 European countries. Also see appendix 1, background information

3.6 *Electrical power demand*

Rising electrical power demand has been identified as one key indicator of the increase in cooling demands. According to (Lucas,1998) the necessary electrical energy to run all refrigerating machines, including air-conditioning plants and heat pumps, accounts for between 10 and 20% of the worldwide electricity consumption. One sixth of the electricity consumed in the US goes to cool buildings. (Loftness, 2002)

The total electrical power demand of Europe has been analysed in order to provide a historical background and represent an attempt to give an estimation of the correlation between electrical power demand and cooling demand with available statistics.

Eurostat statistics on electrical power demand has been used as information source. The data used is the electricity available for inland market given the code with the reference (Eurostat 107200, 2003). The trend of electricity consumption over the last decade could be established for EU 15. Therefore this information has be used for historical trend analysis.

A more detailed research has also been done for the electricity demand during 2003 where statistics were available for 27 European countries. The total national electricity demand figures were used due to lack of monthly data available for demands in building..

3.6.1 Correlation between electrical power demand and cooling demand

Historical trend for the EU15 countries

The annual electrical demand for the EU15 countries is shown in Figure 8. The country codes are provided in Appendix 1. An increase in the electrical power demand/consumption during the last two decades can be noticed. For this period of time a total increase of 50% increase has been has been registered.

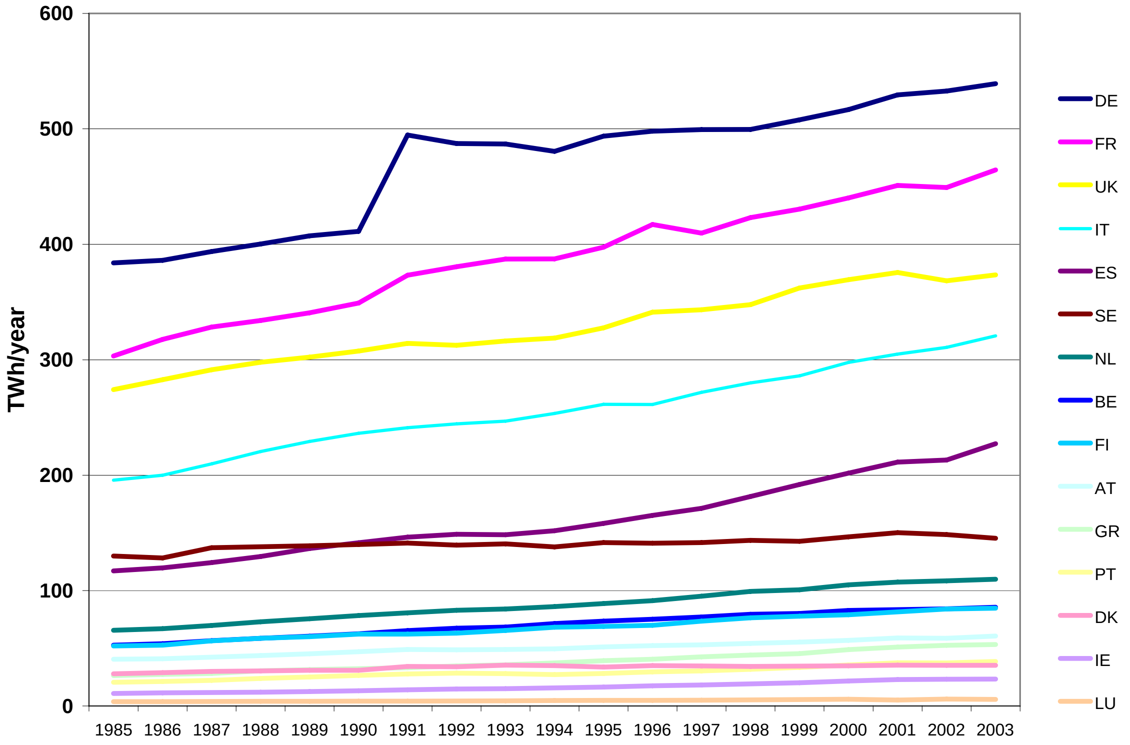


Figure 8 Annual total electrical power demands for the EU15 countries

In order to give an estimate of electricity demand associated with comfort cooling the monthly variation of the electricity demand was analysed. To be able to "isolate" the electricity demand for comfort cooling the electricity consumption of April was compared with the consumption of July. The assumptions behind these choices are that April is assumed to be a heating and cooling neutral month throughout large parts of Europe, whereas July is assumed to be a month of peak, or at least high, cooling demand. The difference between these months was thereafter divided by the annual average demand in order to discover if the difference is growing faster than the average electricity demand.

The ratio was calculated according to Equation 1. The ratio will be positive if the electricity demand is higher in July as compared to April. A high ratio implies that there is a peak in the electricity demand caused by comfort cooling needs.

$$\text{Ratio} = \frac{(\text{demand July}) - (\text{demand April})}{\text{annual average demand}} \qquad \text{(Equation 1)}$$

The ratio has been calculated for the EU15 countries during the time period 1985-2003. Detailed information on the calculated results is shown in Appendix 2. In the Figure 9 the countries are divided into three groups: with positive, shifting and negative ratio during the period 1985-2003. A trend of increasing ratio can be seen for all groups implying that the electricity demand is increasing during summertime as compared to springtime for all EU15 countries.

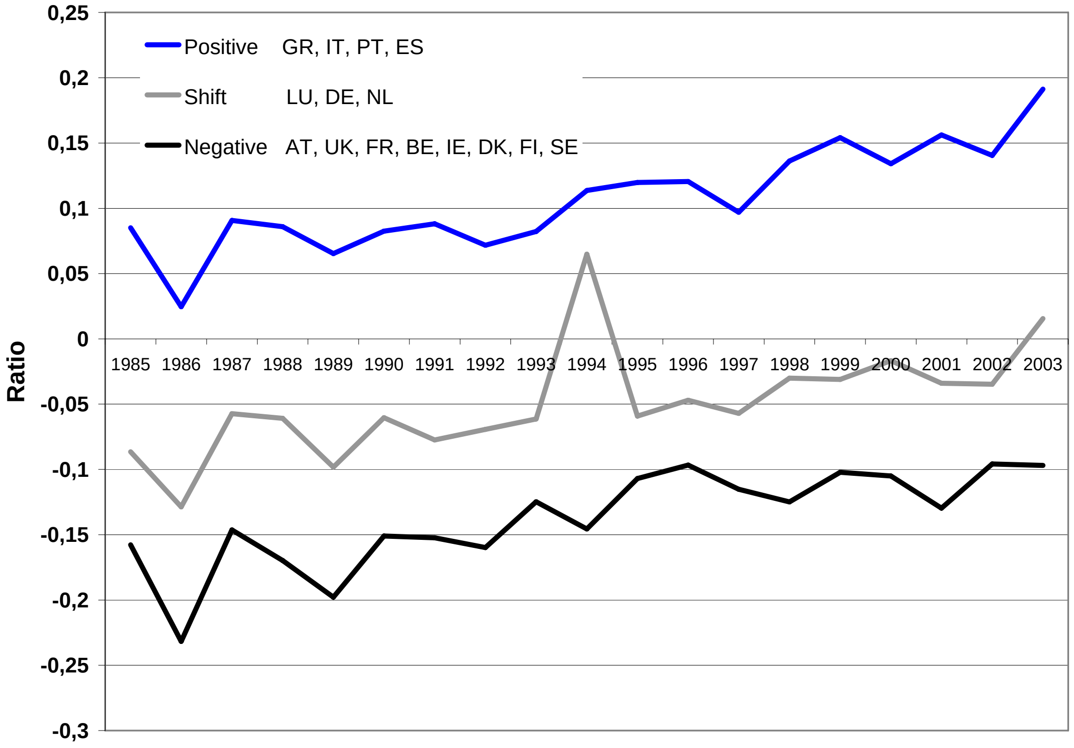


Figure 9 Ratio according to Equation 1 for the three country groups with positive ratio, shifting ratio and negative ratio

The increases in the summer electrical demand implies that the cooling demand is responsible for a growing share of the electricity demand in Europe. As shown in Figure 9 almost half of the 15 countries have shifted to positive ratios at the end of the investigated period. Due to the nature of the statistical data (an aggregated level of total electricity demand) it is not possible to quantify the impact due to the expansion of air conditioning market affecting the specific electricity demand.

3.7 Results and general discussion

An European Cooling Index (ECI) have been constructed based on the same approach as for the European Heating Index (ECOHEATCOOL, WP1, 2005). Although the information about specific cooling demand is limited the ECI shows a good correlation with the actual demand for the ECI range between 60 and100 where most of information has been available.

The result regarding the cooling market for buildings is that the potential in Europe is nearly 1.400 TWh_c, of which about 41% derives from the service sector and 59% from residential sector.

For traditional building bound cooling solutions it is important to underline the poor awareness regarding the actual energy usage for cooling, due to the fact the information on electricity consumption is embedded in a buildings total electricity usage. This implies that specific key-figures and bench mark figures are not collected. Another uncertainty factor is the wide rage of duration time which is due to various system designs and non temperature related cooling use.

The recommendation will be to perform wide rage monitor programs on traditional building bound cooling systems in different ECI regions. It is important to measure not only the electricity consumption related to cooling but also the specific cooling demand, kWh/m^2, and capacity, W/m^2, to further verify the ECI and to improve the knowledge about the impact of cooling on the electrical grid, capacity, and the European electricity use.

In the analysis of the historical trend of the electrical power demand in the EU-15 it has been found that there is an overall increase of the electrical power demand over time. A 50% increase has been found during the years 1985-2003.

Increasing cooling demands might cause increases in electrical power demand particularly over relatively short periods during summer months. The demand in July has been compared to the demand in April. A trend of larger increase of electrical power demand in July as compared to April indicates that production of cooling is responsible for an increasing part of the electricity demand.

The Eurostat statistics on monthly basis are available for the total demand. To be able to perform a more precise analyses of the energy and capacity impact related to cooling demands a recommendation to Eurostat will be to collect and present more precise statistics regarding electricity consumption for different type of use within different building sectors and sub-sectors and on shorter timely based periods : 24 hours or even 1 hour.

4 Cooling markets

4.1 Cooling technologies

4.1.1 Conventional cooling/air-conditioning

Today the building bound cooling systems are the dominating solution for cooling / air condition in service sector buildings.

The building-bound cooling supply is either produced centrally or locally in the building.

Central air-conditioners

- Packaged air conditioning equipment. Includes all direct expansion (DX) systems. The warm air in a room is cooled by passing it directly through copper pipes which contain the cold refrigerant vapour. Multiple split systems, ducted packaged systems and roof-tops are also defined as packaged plants.
- Central plant air conditioning equipment. These are usually larger systems based on Chillers. One or more chillers are located in a central place and produce cold water. This cold water can either be piped to air handling units which distribute the cold air within the building with the ventilation system and/or to individual fan coils, inductor or beams located throughout the building.

Local air-conditioners

Individual room by room units so call RAC (room air conditioners) - EU definition - Air conditioning systems with less than 12 kW of cooling capacity.

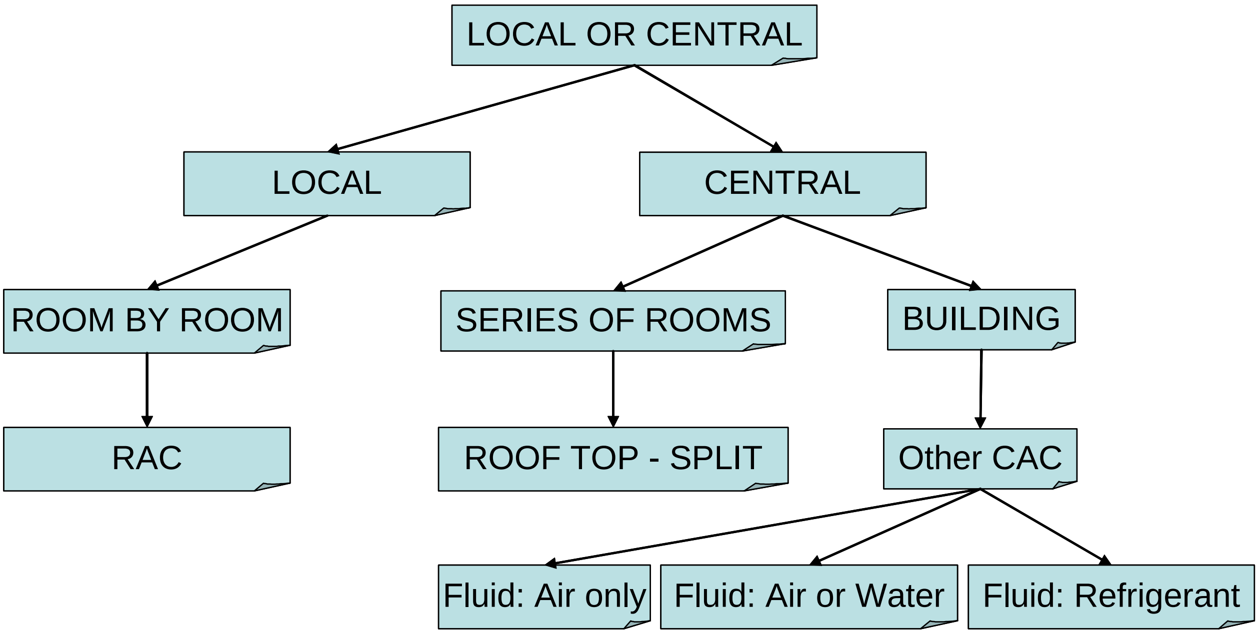


Figure 10 CAC and RAC system description showing the most common systems, "fluid" refers to the primary energy transfer fluid within the building. (EECCAC, 2003 and EERAC, 1999)

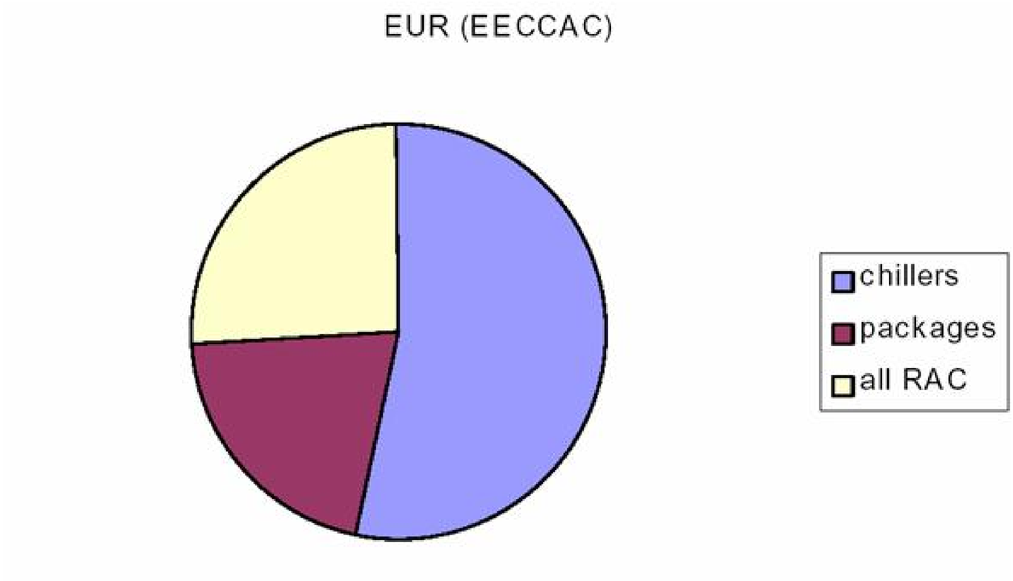


Figure 11 The share of cooled-floor area by air-condition type in the service sector in EU-15 for 1999/2000

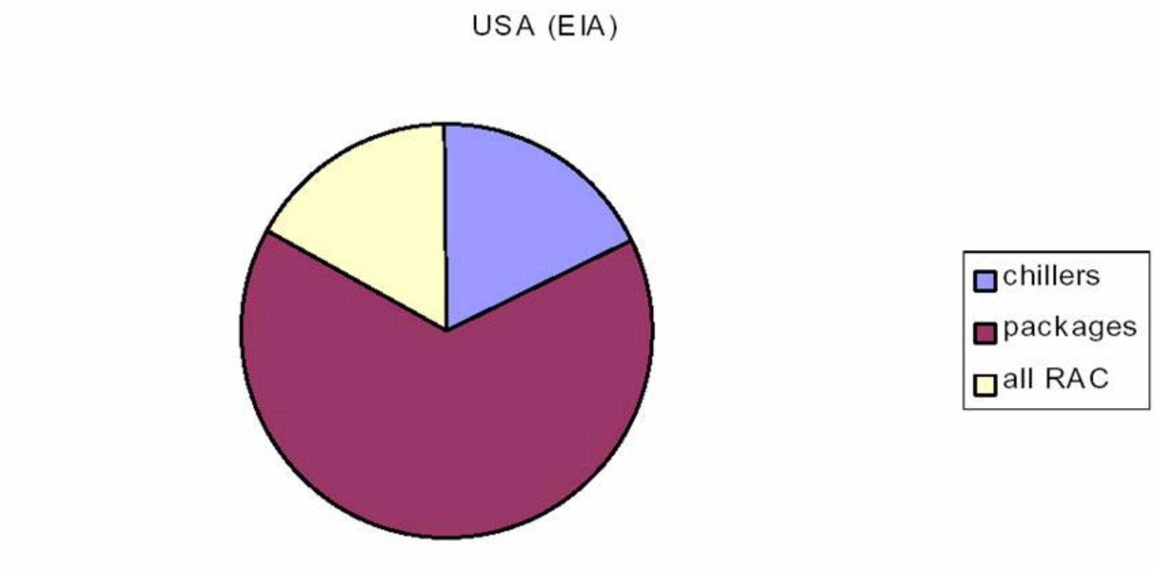


Figure 12 The share of cooled-floor area by air-condition type in the service sector in US for 1999/2000

In the EECCAC report chillers are accounting for 50 % market share of installed capacity. However this is changing quickly as the packaged systems are showing a 70% share of present sales.

This trend follows the market pattern in the US where chillers (according to EECCAC, 2003) have a market share below 20%.

For more information about conventional cooling/air-conditioning technologies and there performance the two EU funded studies (EECCAC, 2003 and EERAC, 1999) give deeper information.

General advantages of the central systems are:

- Better preconditions for improved energy efficiency and lower capacity use due to total system overview and better monitoring and operation strategy possibilities
- Buildings designed for central systems have an internal infrastructure prepared for connecting a district cooling system

In work package 5 these systems competitive position with district cooling will be further analysed.

4.1.2 District cooling

District cooling refers to cooling that is commercially supplied through a cold/heat carrier medium against payment on the basis of a contract. District cooling can take different forms. It can be a network serving several customers; it can also refer to the local production and distribution of cooling for meeting the needs of an institution - business centres, airports, hospitals, universities and public buildings. Experiences demonstrate that this type of block cooling can be the starting point of a district-cooling network when new users are added.

The centrally produced district cooling solution can reach 5 to or even 10 times higher efficiency than traditional local electricity-driven equipments. It also opens a great flexibility, tailored to users' needs, to combine cooling production with different possibilities such as:

- deep sea or deep lake water "free cooling"
- absorption chillers (in combination with waste heat production from industrial sources, waste burning plants or cogeneration production plants)
- heat pumps in combination with heat demand (i.e. district heating systems)
- To increase the efficiency and reliability, these cooling sources and production techniques are often combined with different kinds of storage solutions, such as:
- seasonal storage where free cooling in winter is stored for use during the summer period
- night to day storage facilities where overcapacity during the night is stored for use during daytime.

The centralisation of cooling production is a prerequisite to reach a high efficiency insofar as it makes possible to use "free cooling" or waste heat sources, and thereby reap benefits brought by a large-scale production of energy. A distribution network is therefore necessary to enable the cooling supply to the customers.

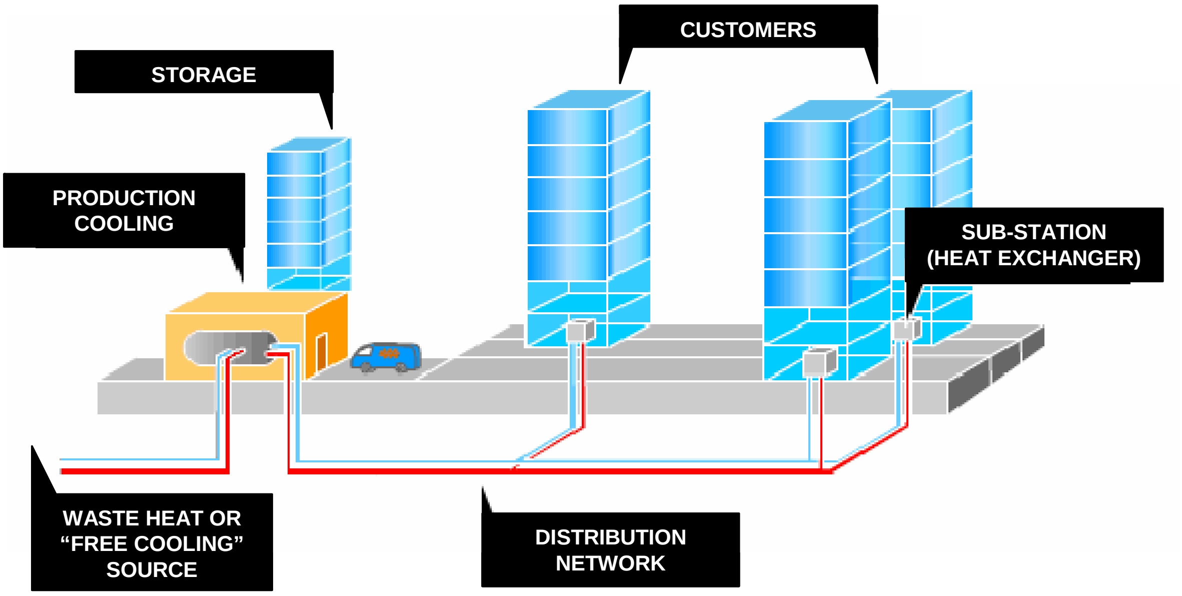


Figure 13 District cooling system

District cooling can be produced in different ways. The technology chosen always depends on economical factors, local energy systems and also on natural resources available.

4.1.2.1 Production

In the production plant one of or a combination of the following production and storage techniques are the most common.

Combining district Heating/Cooling

"Surplus cooling" can be used from heat pumps that are originally intended for supplies into district heat, operating on, for instance, seawater or waste water. By connecting the cold side of the heat pumps to a district-cooling system, the heat pumps can be used for simultaneous production of heat and cold.

Absorption chillers

Absorption chillers use heat as primary energy and not electrical power as is the case for conventional compression chillers. The benefits of this technology compared to conventional chillers are that the electrical power consumption is dramatically reduced and primary energy is used more efficiently. Surplus heat from, among others, municipal waste incineration, industrial processes and power production may be utilized for cooling production by integration of an absorption chiller to the plant.

The cooling production can also be distributed out in local areas or buildings using the district heating system as the distributor of the waste heat to the local absorption chillers. This dependency can imply higher distribution temperatures on the district heating system during the summer. This consequence has to be deeply analysed before entering into this distributed solution.

As the heat demand is seasonal and low during summer time, cooling production through an absorption chiller enable to increase the efficiency of the plant by using excess heat that is available while displacing less environmentally friendly alternatives.

"Free cooling"

The concept refers to the extraction of available cold water. It can be compared to the use of geothermal energy in district heating systems. The cold water required to cool down buildings can be found in oceans, lakes or rivers and aquifers.

Via heat exchangers the cold is transferred to the distribution network and delivered to the customers where the cold is used in the cooling infrastructure of the building. The maximum cooling temperature delivered to customers can be guaranteed with - if needed - additional cold added from different sources.

Such a system can be developed when the water temperature is cold enough and when the plant is close to the buildings where the water is carried. The advantage of free cooling is that it offers cooling on a renewable basis. Such schemes exist in Europe (Stockholm, Helsinki) and North America (Toronto).

Industrial chillers

High efficient industrial chillers can be added as a part of the production mix to secure outgoing temperatures and redundancy and/or for peak capacity.

4.1.2.2 Storage

To increase the efficiency and reliability, these cooling sources and production techniques are often combined with different kinds of storage solutions, such as:

Seasonal storage

Seasonal storage, often performed as an aquifer solution, where free cooling in winter is stores for use during the summer period

Night to day storage

Night/day storage often performed as ice or water storage solutions. Overcapacity during the night is stored for use during daytime.

4.1.2.3 Distribution

In a district cooling network, the chilled water is distributed to buildings where it loses its cold content, thus cooling down the building temperature; the warmed up water is then returned to the central production facility. The supply temperature is normally between 6 and 7°C, but an ice mixture of 0°C is used in some cases. The typical temperature in the return pipe is 12 to 17 °C. The supply of cooling to the user can also be done through a district heating systems coupled to absorption chillers at the user's location.

4.1.2.4 Sub-station

The customer interface or the "sub-station" is usually an indirect connection via a heat exchanger, the same technology as for district heating. The substation is not only the connection point and the contract boundary between the supplier and the customer but has also a digital connection for measurements of the cooling delivery. This information is also used for delivering additional energy services to the customer such as energy declarations, alarms and bench marking information. Therefore the delivery of district cooling can be associated with an energy service insofar as it brings substantial benefits in terms of comfort and energy savings to the customer.

4.2 Energy efficiency of cooling solutions

To be able to compare the energy efficiency of different cooling solutions for a building an integrated approach for the whole system instead of building level approach is needed. The energy input must therefore be compared as all the energy input is needed for the cooling production and cooling distribution for the entire system.

Table 3: Performance of different cooling solutions[1]

Solutions	EER	PRF
Conventional building bound solutions		
Conventional RAC and CAC	1,5-3,5	1,7-0,7
Conventional chillers combiened with aquifers	3-6	0,8-0,4
District cooling solutions		
Industrial chillers with efficient condenser cooling and/or recovered heat to DH	5-8	0,5-0,3
Free cooling / industrial chillers	8-25	0,3-0,1
Free cooling	25-40	0,1-0,06
Absorption chiller driven from heat from waste or renewable source	20-35	0,13-0,07

EER =(Seasonal System) Energy Efficiency Ratio. This states the output of yearly useful cooling energy per unit of yearly electrical energy input in the system. (base for financial calculations)

PRF =Primary Resource Factor. (based on environmental/primary resource impact analysis)

4.3 Market development

As explained above the acceptance of air conditioning is changing, to a more positive attitude. The air conditioning is considered "healthy" and not an expensive option as the initial perception might suggest.

---

[1] A more thorough description of how primary resource factor (PRF) relates to the Energy Efficiency Ratio is explained in the ECOHEATCOOL work package 3 (WP3) of this project that is dealing with the question of "*Guidelines for assessing the efficiency of district heating and district cooling systems*".

Driving factors for strong growth

- Increasing affordability
- Shifts in comfort culture, behavioural patterns and consumer expectation
- Increase in internal heat loads (computers etc.)
- Increase in urban heat island phenomenon and a general trend towards higher temperatures
- Perception that comfort cooling contribute to higher productivity
- Movement to universal building designs which are poorly adapted to the local climatic conditions

Market experience from US also shows that once 20% of the office space in a city is air conditioned it sets the rental value and un-cooled space only can be let at discount. For building developers/owners un-cooled commercial building could be treated as a risky commercial option.

The cooling market is dominated by a number of global OEMs (original equipment manufacturers) operating with national or regional sales offices throughout Europe. They integrate with local installation and operation and maintenance partners in order to provide the service levels required to be competitive.

The role of national players is diminished, due to mergers or acquisitions from international actors.

In the niche market of district cooling energy operators such as local energy companies as well as FM (facility management) players/ESCOs play a role.

The following main three business models are applied in the cooling market:

1. The final user owns his cooling generating equipment and buys a continuous flow of an energy commodity in order to generate the cooling. This is the dominating way in Europe, since the OEMs of tradition see themselves as system suppliers. The final user buys the cooling equipment initially from an equipment supplier and make contract with the local electricity net operator makes is possible to provide electricity from a supplier.
2. The final user buys the cooling directly from an urban district cooling system or a local production plant owned by the supplier. After signing a negotiated contract the delivery is initiated by the connection to the district cooling network or that the customer cooling equipment is either sold to or installed by the supplier. The cooling is continuously delivered according to a contract stipulating the product quality and the cooling flow depends on control set points fixed by the final user.
3. A variant of version 2 is that the supplier also is responsible for the control set points and the final user pays for a cooling service expressed and defined in a contract. This version is often referred as an ESCO arrangement.

These business models reflect the commitment of the final user. In the first version, the final user must take active part in choices of cooling equipment, type of system and maintenance services. The final user is more passive in the two other versions, focusing on core business or private interests, and is buying a more refined product. When comparing the total cost for the three models, it is important to consider the maintenance cost, which is additional in the first model, but included in the other two models.

The three different versions of business models give a demand for different market players. In the first case the focus is on standardised air conditioning equipment and a service package, while remote monitor and control, heat exchangers, and prefabricated distribution pipes are inevitable building blocks in the second model.

If we compare the European market, EU-15 with Japan and US the saturation for both residential and service building is far higher.

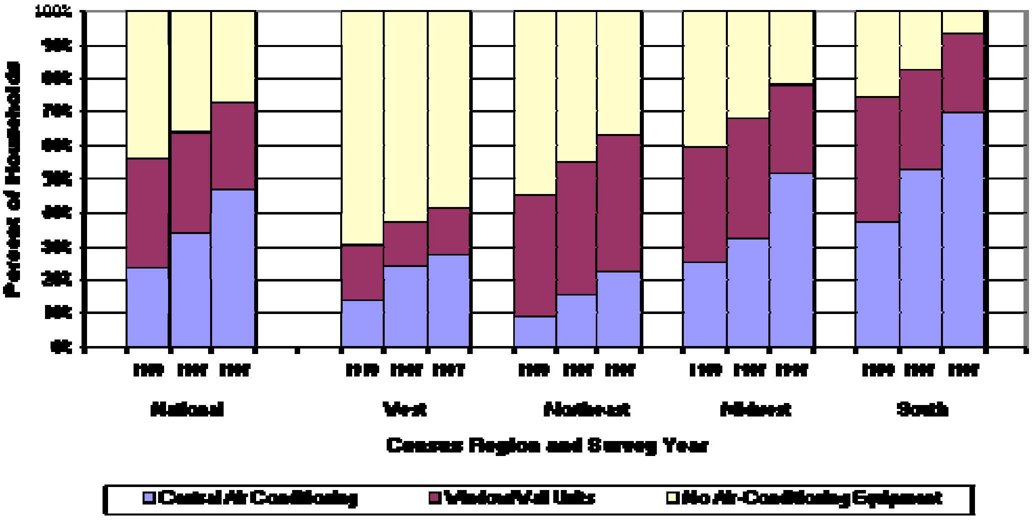
Service buildings:

In US the total amount of cooled service buildings floor space is equal to 73% of the useful floor space (IEA, 1999).

According to (Centre of Energy and Processes, 2003) the corresponding figure for Japan was nearly 100% in 1997 while the saturation level in EU-15 was estimated to 27 % in the same year.

Residential buildings:

The US picture for residential building is well grasped in the table below



Sources: Energy Information Administration; [illegible], [illegible], and [illegible] Residential Energy Consumption Surveys.

Figure 14

As shown in the Figure 14 the US market has seen a steady growth also for the residential sector and in 1997 the saturation level nationally was about 70%.

The pattern for Japan show even higher share at about 85% while EU-15 only had a saturation of 5 % in year 2000. (Centre of Energy and Processes, 2003)

However the market development in Europe has experienced a major expansion during the last decades, this trend is likely to continue.

According to a study from (EECCAC, 2003) the annual cooling installations in EU-15 has experienced a fourfold increase between 1980 and 2000.

The growth has been particularly strong in south Europe and is mainly due to that standard of living has made this type of equipment affordable and that comfort standard requirements have increased. Residential air conditioning penetration in Italy, Spain and Greece is today between 25-35% and steadily increasing. A strong development of the service sector especially office buildings explain the higher growth in central Europe (Germany) compared to Portugal and France.

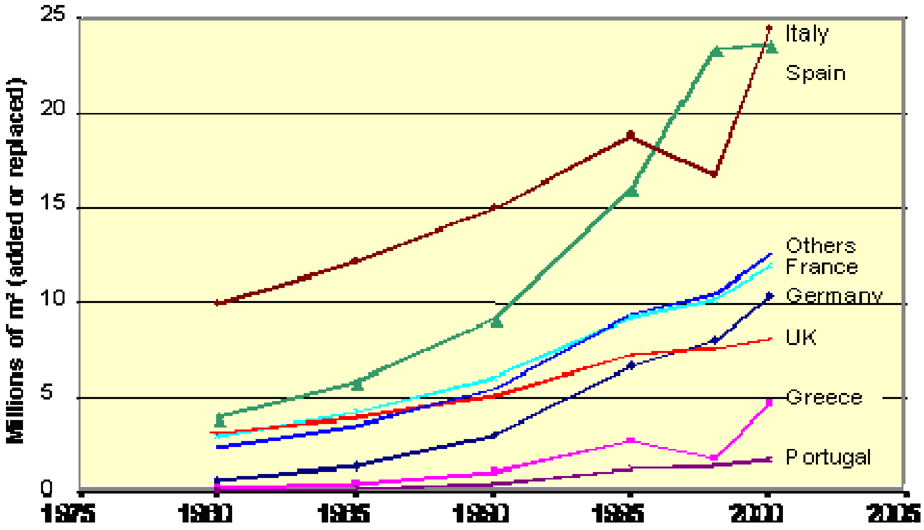


Figure 15 Apparent annual additional building floor area conditioned by 2000 according to (EECCAC, 2003)

By studying statistical data for the air conditioning equipment market an indication about market expansion speed can be obtained.

The Japan Refrigeration and Air-conditioning Industry Association (JRAIA) has done a survey estimating the demand for air-conditioners (IIR newsletter, 2003). The survey showed that the number of air-conditioners in the world is increasing rapidly which will have a direct effect in electricity consumption. At a global level, the demand for 2002 was estimated by JRAIA to be 44.6 million units with a predicted level of 52.3 million units in 2006.

A market survey for EU-15 conducted by BSRIA (BSRIA reports, 2004) suggests a 30 % increase, which corresponds to the value of installed equipment during the period 2001-2004.

An air conditioning equipment market survey conducted in 6 countries (UK, France, Germany, Italy, Spain and Greece) for 2004, show a total market development with an annual growth at approx. 14%. (BSRIA, 2005)

For packaged air conditioning equipment the growth was 20 % between 2003 and 2004 while the chillers market show a more moderate increase of about 2%. According to forecasts presented in the same market surveys this trend is expected to continue.

Another important trend detected in this survey is how the sales of new equipment are used, i.e. how much is replacement and how much is new annual additional building floor area conditioned.

The sales of packaged systems during 2004 were dedicated to:

- New buildings 25%
- Refurbished 50%
- Replacement 25%

Corresponding figures for chillers were

- New buildings 35%
- Refurbished 30%
- Replacement 35%

I.e. a very large proportion of annual sales is directed towards sectors that is non replacement (72%).

A forecast estimation for the cooling market in Europe:

A development towards the cooling saturation level as in USA of 70 % for the residential and 73% for the service sector is probably not likely due to differences in climatic conditions. By looking at market trends in Europe more likely is to have a saturation rate of 60% for service sector and 40% for the residential sector. This would result in a cooling demand of 660 TWh_c per year for all target area and 500 TWh_c per year for EU-15.

If we assume that EU-15 had a market size at 130 - 150 TWh_c in 2000 with saturation rates of 27% for the service sector respectively 5 % for the residential sector (Centre of Energy and Processes, 2003) an expansion rate equal to the situation between 1980 and 2000 would imply that " The European saturation rate" will be reached 2018.

Another faster expansion scenario can be derived by looking at sales of air conditioning equipment with the rate for 2004 corresponding to a market increase of more than 50 TWh_c in EU-15 (sales to non replacement to both residential and service sector).(BSRIA, 2005)

With this expansion pace "the European saturation rate" could be reached already around 2012.

4.3.1 Suppliers of conventional cooling/air-conditioning

More and more the European market is dominated by the global mini split players from Japan, Korea and Thailand (i.e. Daikin, Mitsubishi, Toshiba, Samsung etc). On the chillers market Carrier, Trane, Quay and York have tighten their grip on the European market with a second tier group Ciat, Lennox, Clivet etc. which still keep a certain stronghold on their home markets.

4.3.2 Suppliers of district cooling

District cooling has successfully developed in some densely populated areas in Europe as supplier to the service sector, and in some cases, also to the residential and industry sectors.

District cooling networks are operated by energy- utility- and ESCO companies, in several countries – as illustrated below, and many new systems are under development or in the feasibility study phase.

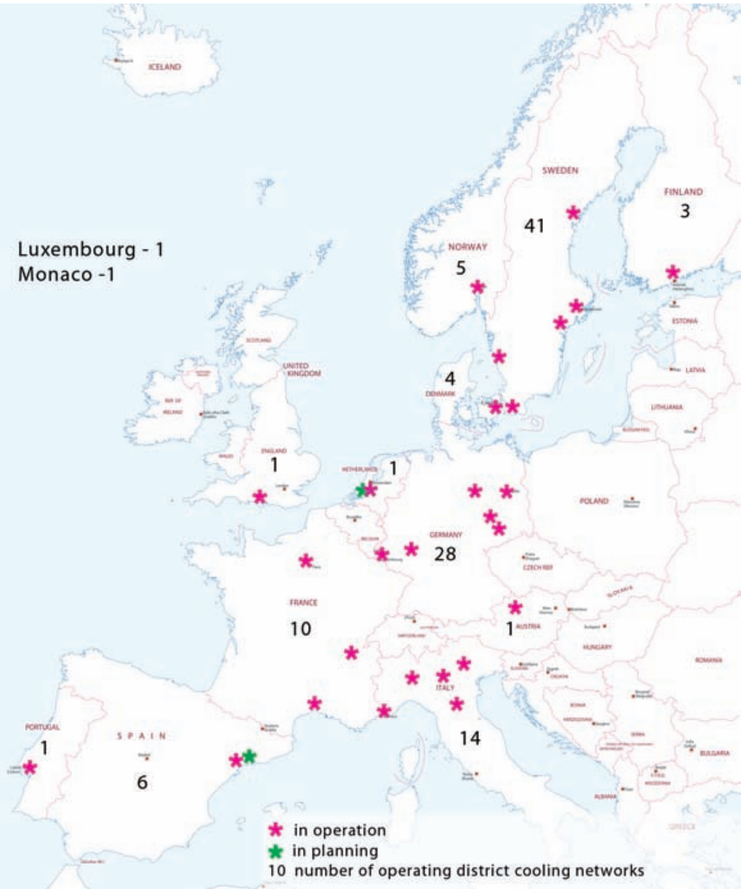


Figure 16 Indicative mapping of cooling networks and on-site cooling installations (5 biggest indicated per country)

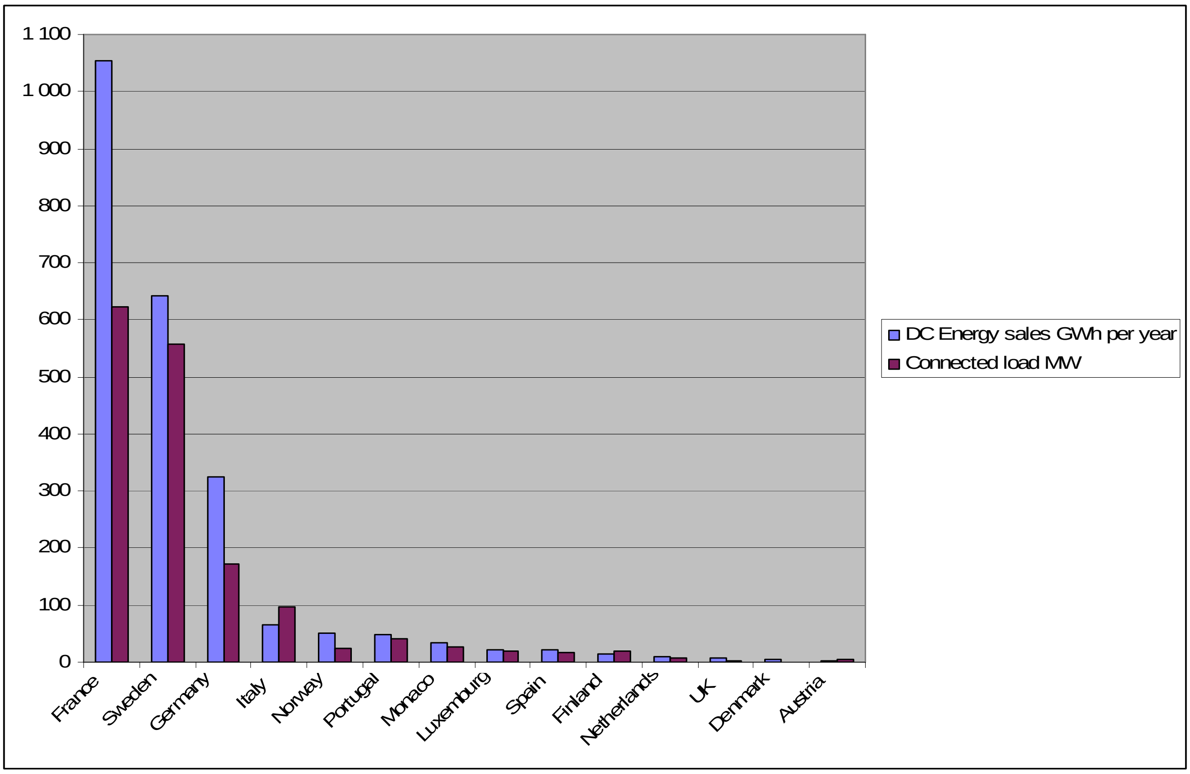


Figure 17 District cooling – 2003 statistics

The market share of district cooling is today about 1-2% or between 2 to 3 TWh_c of the total cooling market.

There are different reasons behind the development of district cooling. The development of a district cooling network is always a win-win process for a range of different players. On the customers' side, buildings owners are increasingly keen on outsourcing operations to external companies with a view to developing productivity and gain on optimisation of energy use. For energy companies, the development of a district-cooling offer is an attractive choice to enter new markets and get closer to the end-user. Last but not least, for a city, the district-cooling option enables a sustainable supply of cooling with the ensuing environmental and economic advantages in terms of quality of life, attractively of the city and a better urban design.

In some Member States, its development could rely on experience in district heating like for instance in Helsinki, Paris and Stockholm. In other cases, the development is more recent and embedded in innovative local urban projects like in Barcelona and Lisbon.

The choice to manage energy in a more rational way systematically lies in the background of all projects. Different factors have played a role in the development of district cooling such as the priorities laid down in the respective regulatory frameworks, and the investment climate. Last but not least, the influence of climatic conditions and the design of local demands play a role and impact on the choice of technologies in district cooling networks.

The suppliers of district cooling will be further described in the succeeding report within ECOHEATCOOL.

4.3.3 Cooling costs and prices

Conventional cooling/air conditioning

Costs for air conditioning and other cooling purposes can be divided in two parts according to the way the technical systems are divided in primary and secondary sub systems. The cooling production takes place in the primary system whereas the cooling distribution within the building takes place in the secondary system. In this study, the costs for secondary systems are not included.

Costs for cooling production (primary system) may be broke down to a large number of fixed and flexible cost items, appearing with very disperse frequencies over time. Procurement of chillers may occur every 15 years, while electricity is more or less a continuous cost. To get a fair picture of the cooling costs over time, an average cost over a certain period of time (e.g. life cycle cost) has to be calculated.

Normal cost items for calculation of the cooling cost are:

- Equipment and installations (Investments and re-investments in primary and secondary systems)
- Cost for building area used for cooling production
- Electricity costs (Grid fees due to cooling installation, commodity cost, taxes, environmental fees)
- Operation and maintenance (fixed and flexible operation costs, planned & unplanned maintenance)
- Administrative costs (permissions, reporting to authorities (use of chemicals etc))

Hence, the total cooling cost is very much depending on the local market prices of the different cost items. For example interest rates, electricity prices, taxes and labour costs varies widely within Europe, but they also varies over time, and therefore it is not feasible to give a fair picture of it within the scope of this study.

For indicative levels the following example is given:

- The two most dominant components are the investments and the electricity price. Since cost of the investments for the installed capacity is very much depending on the operational strategy (the conventional cooling industry tends to overestimate the needed capacity and underestimate the full load hours). In this example a central plant air condition system with a demand of 80 kWh/m^2 and an installed capacity of 80W/m^2 are used and only the costs for the primary side i.e. out from the production plant are included:
    - Investment: Chillers, Cooling Towers, Electricity equipment, Building, installations auxiliary etc. gives 40-70 €/MWh$_c$
    - Electricity: With a primary system efficiency ratio of 2,5 and an electricity price of 70-150 €/MWh$_c$ the electricity cost would be 30-60 €/MWh$_c$
    - Other fixed and variable costs 10-20 €/MWh$_c$
- In this example the cost varies between 80 to 150 €/MWh$_c$

District Cooling

Regarding district cooling, the pricing of the district cooling product is derived mostly from a negotiation process between the supplier and the customer where agreements are closed based on alternative pricing solutions in bilateral contracts. These individual deals are confidential information but can be estimated by performing alternative price calculations as above. Indicative information has thus been received by interviews with district heating/cooling associations and information in annual reports shows price levels between 60 and 120 €/ MWh_c and is in line with the range of the levels for customer price calculations.

4.4 Results and general discussion

The building bound solutions are dominating solution for cooling / air condition in both service and residential buildings, with DC accounting for a market share of 1-2%.

Earlier studies have predicted that Europe will reach about 300 TWh_c in 2020 (EECCAC, 2003).

All analysed information sources showed that a strong market expansion has taken place during the last decade and forecasts that this trend will continue. The growth is mainly due to the fact that the increased standard of living has made this type of equipment affordable. Moreover the people comfort standard requirements have increased. Market experience from US also shows that once 20% of the office space in a city is air conditioned it sets the rental value and un-cooled space only can be let at discount. For building developers/owners un-cooled commercial building could be treated as a risky commercial option.

With a saturation rate of 60% for the service sector and 40% for the residential sector - “the European saturation rate” the cooling market will show a four fold increase between 2000 and 2018, corresponding to 500 TWh_c for the EU-15. This is about 200 TWh_c higher that earlier predictions (EECCAC,2003). For all 32 countries this would correspond to 660 TWh_c,

In a faster expansion scenario based on the present air condition equipment sales expansion rate the above market figures could be reached already by 2012.

Another element which can contribute to an even higher pace of expansion and demand levels is the increase of the useful floor space per capita for the EU-10 when the GDP will rise.

Specific price for cooling €/MWh_c is highly depending on the electricity price and the efficiency of the equipment. Also the wide rage of full load hours due to non temperature factors makes the price spread for cooling wide and transform €/MWh_c in a highly individual and a poor bench-mark figure.

5 References

Ecoheatcool-WP1,2005, Ecoheatcool-WP1, The European Heat Market 2003, November 2005

Eurostat,2005, Eurostat, the online database for Energy and Environment, table es_106a, available at the Eurostat website epp.eurostat.cec.eu.int

Eurostat,2002, Eurostat, statistical information on energy consumption for the service sector

Lucas, 1998, Lucas L., 1998, *IIR news*, International Journal of Refrigeration, Vol. 21, No., 2, pp. 87-88

IIR, 2003, IIR, 2003, *International Institute of Refrigeration newsletter*, No 13, August 2003

Repab Fakta, 2001, Repab Fakta, *Årskostnader Kontor*, 2001

EECCAC, 2003, EECCAC "Energy Efficiency and Certification of Central Air Conditioners", D.G. TREN, April 2003

EERAC, 1999, EERAC " Energy Efficiency of Room Air-Conditioners", D.G.Energy (DGXVII), May 1999

IEA, 1997, Residential Energy Consumption Survey Office of Energy Markets and End Use

IEA, 1999, Commercial Buildings Energy Consumption Survey 1999

IEA,2005, Energy balances for OECD countries 1960-2003, available on CD-ROM or online at www.iea.org , Paris 2005

IEA,2005, Energy balances for non-OECD countries 1971-2003, available on CD-ROM or online at www.iea.org , Paris 2005

IEA,2004, Cooling buildings in a warming climate, Sophia Antipolis (Côte d'Azur), France 21–22 June 2004 available at

www.iea.org/dbtw-wpd/Textbase/work/2004/cooling/presentations.htm

Euroheat & Power, District Heating and Cooling, country by country survey 2005. Brussels 2005.

Boverket, Boverket (The Swedish National Board of Housing, Building and Planning), Housing Statistics in the European Union 2004. Karlskrona 2005. Available at http://www.boverket.se

Silpilä,Ranne, Aaltonen,2004, Silpilä, Ranne, Aaltonen, Analysing cooling production costs in buildings, Osat 1-3, 2004

CEP,2003, Centre of Energy and Processes, 2003, http://www-cenerg.ensmp.fr

UN,2004, UN, Urban and rural areas 2003, United Nations Department of Economic and Social Affairs, Population Division 2004, available at http://www.un.org/esa/population/publications/wup2003/2003urban_rural.htm

UNECE,2005, UNECE (United Nations Economic Commission for Europe), Bulletin of Housing Statistics for Europe and North America 2004. Geneva 2005. Available at http://www.unece.org/

DEA, 2005, European district energy associations Interviews with the European district energy associations

BSRIA, 2004, World market for air conditioning

BSRIA, 2005 , European market for air conditioning

Looftness,

2002, The Austin Papers Building green by V Loftness

Eurostat 107200, 2003, The Eurostat data base

Appendices

Appendix 1. Background information

Table 4 Population and GDP

Country	Country label	Country group	Population 2003, millions	GDP 2003, Billion EUR	GDP/capita, EUR	GDP PPS 2003, Billion EUR	GDP PPS/capita EUR
Austria	AT	EU15	8,1	226	27846	211	26035
Belgium	BE	EU15	10,4	270	25978	260	25060
Bulgaria	BG	ACC4	7,8	18	2266	50	6341
Croatia	HR	ACC4	4,4	26	5797	43	9774
Cyprus	CY	NMS10	0,7	12	16120	13	17486
Czech Republ	CZ	NMS10	10,2	80	7847	149	14624
Denmark	DK	EU15	5,4	187	34715	140	25983
Estonia	EE	NMS10	1,4	8	5942	14	10463
Finland	FI	EU15	5,2	143	27496	127	24272
France	FR	EU15	59,8	1557	26055	1480	24759
Germany	DE	EU15	82,5	2165	26230	1931	23402
Greece	GR	EU15	11,0	153	13911	190	17237
Hungary	HU	NMS10	10,1	73	7228	129	12768
Iceland	IS	EFTA3	0,3	9	31789	7	24817
Ireland	IE	EU15	4,0	135	33733	113	28159
Italy	IT	EU15	57,6	1301	22584	1310	22750
Latvia	LV	NMS10	2,3	10	4244	20	8721
Lithuania	LT	NMS10	3,5	16	4711	34	9744
Luxembourg	LU	EU15	0,4	24	53241	21	45706
Malta	MT	NMS10	0,4	4	10576	6	15518
Netherlands	NL	EU15	16,2	454	27998	418	25741
Norway	NO	EFTA3	4,6	195	42752	143	31396
Poland	PL	NMS10	38,2	185	4848	374	9785
Portugal	PT	EU15	10,4	131	12500	166	15900
Romania	RO	ACC4	21,7	50	2316	138	6330
Slovak Republ	SK	NMS10	5,4	29	5382	60	11138
Slovenia	SI	NMS10	2,0	25	12314	33	16348
Spain	ES	EU15	41,9	745	17785	890	21260
Sweden	SE	EU15	9,0	267	29833	220	24524
Switzerland	CH	EFTA3	7,3	285	38818	204	27854
Turkey	TR	ACC4	70,7	212	3002	417	5898
United Kingd	UK	EU15	59,4	1591	26779	1515	25489
Total			**572,5**	**10587**	**18494**	**10825**	**18911**

Table 5 Calculation of Specific cooling demand

Country	ECI	Total residential area	Total service area	Specific cooling demand		Cooling total potential		
				Residential	Service	Residential	Service	Total
	-	million m2	million m2	kWh/m2	kWh/m2	TWh	TWh	TWh
Germany	94	3492	1852	35	77	121	143	264
Italy	133	2395	453	49	109	117	49	166
France	95	2643	861	35	78	93	67	160
Spain	147	1885	341	54	121	102	41	143
Turkey	135	1542	268	50	111	77	30	107
United Kingdom	74	2226	892	27	60	60	54	114
Poland	95	802	382	35	78	28	30	58
Greece	161	452	149	59	132	27	20	47
Romania	137	530	87	50	112	27	10	36
Portugal	104	441	126	38	85	17	11	28
Netherlands	65	667	183	24	53	16	10	26
Hungary	123	310	101	45	101	14	10	24
Austria	106	308	119	39	87	12	10	22
Belgium	77	416	151	28	63	12	10	21
Sweden	73	399	161	27	60	11	10	20
Switzerland	85	324	136	31	70	10	10	20
Czech Republic	89	333	100	33	73	11	7	18
Bulgaria	116	233	31	43	95	10	3	13
Slovak republic	117	173	81	43	96	7	8	15
Denmark	59	279	114	22	48	6	5	12
Finland	72	198	101	27	59	5	6	11
Croatia	127	131	33	47	104	6	3	10
Norway	67	212	95	25	55	5	5	10
Slovenia	127	59	16	47	104	3	2	4
Lithuania	85	78	14	31	70	2	1	3
Ireland	32	162	58	12	26	2	2	3
Latvia	79	54	23	29	65	2	2	3
Cyprys	143	33	7	53	118	2	1	3
Estonia	65	38	14	24	54	1	1	2
Malta	143	14	4	53	118	1	0	1
Luxembourg	81	22	7	30	67	1	0	1
Iceland	6	16	7	2	5	0	0	0
TOTAL		**20 867**	**6 966**			**807**	**560**	**1 367**

					Residential TWh	Service TWh	Total TWh
ACC4	2437	420	190	423	120	46	166
EFTA3	551	237	58	130	15	15	30
EU15	15986	5567	506	1127	601	438	1039
NMS10	1894	742	393	876	71	61	132

Table 6 Estimated saturation of Cooling per country EU-15, year 2000

Country	ECI	Total residential area	Total service area	Cooling after saturation			Electricity demand for cooling		
				Residential	Service	Total	Residential	Service	Total
	-	million m2	million m2	TWh	TWh	TWh	TWh	TWh	TWh
Germany	94	3492	1852	6	39	45	2	15	18
Italy	133	2395	453	6	13	19	2	5	8
France	95	2643	861	5	18	23	2	7	9
Spain	147	1885	341	5	11	16	2	4	6
United Kingdom	74	2226	892	3	15	18	1	6	7
Greece	161	452	149	1	5	7	1	2	3
Portugal	104	441	126	1	3	4	0	1	1
Netherlands	65	667	183	1	3	3	0	1	1
Austria	106	308	119	1	3	3	0	1	1
Belgium	77	416	151	1	3	3	0	1	1
Sweden	73	399	161	1	3	3	0	1	1
Denmark	59	279	114	0,3	1,5	1,8	0,1	0,6	0,7
Finland	72	198	101	0,3	1,6	1,9	0,1	0,6	0,8
Ireland	32	162	58	0,1	0,4	0,5	0,0	0,2	0,2
Luxembourg	81	22	7	0,0	0,1	0,2	0,0	0,0	0,1
TOTAL		**15 986**	**5 567**	**30**	**118**	**148**	**12**	**47**	**59**

Not: The same saturation levels for all countries are assumed

Table 7 Estimated saturation of Cooling per country, corresponding to US saturation, 1997-1999,

Country	ECI	Total residential area	Total service area	Cooling after saturation			Electricity demand for cooling		
				Residential	Service	Total	Residential	Service	Total
	-	million m2	million m2	TWh	TWh	TWh	TWh	TWh	TWh
Germany	94	3492	1852	85	105	189	34	42	76
Italy	133	2395	453	82	36	118	33	14	47
France	95	2643	861	65	49	114	26	20	46
Spain	147	1885	341	71	30	101	29	12	41
Turkey	135	1542	268	54	22	76	22	9	30
United Kingdom	74	2226	892	42	39	82	17	16	33
Poland	95	802	382	20	22	42	8	9	17
Greece	161	452	149	19	14	33	8	6	13
Romania	137	530	87	19	7	26	7	3	10
Portugal	104	441	126	12	8	20	5	3	8
Netherlands	65	667	183	11	7	18	4	3	7
Hungary	123	310	101	10	7	17	4	3	7
Austria	106	308	119	8	8	16	3	3	6
Belgium	77	416	151	8	7	15	3	3	6
Sweden	73	399	161	8	7	15	3	3	6
Switzerland	85	324	136	7	7	14	3	3	6
Czech Republic	89	333	100	8	5	13	3	2	5
Bulgaria	116	233	31	7,0	2,2	9,1	2,8	0,9	3,7
Slovak republic	117	173	81	5,2	5,6	10,8	2,1	2,3	4,3
Denmark	59	279	114	4,2	4,0	8,2	1,7	1,6	3,3
Finland	72	198	101	3,7	4,4	8,1	1,5	1,7	3,2
Croatia	127	131	33	4,3	2,5	6,8	1,7	1,0	2,7
Norway	67	212	95	3,7	3,8	7,5	1,5	1,5	3,0
Slovenia	127	59	16	4,3	2,5	6,8	1,7	1,0	2,7
Lithuania	85	78	14	1,7	0,7	2,5	0,7	0,3	1,0
Ireland	32	162	58	1,3	1,1	2,4	0,5	0,4	1,0
Latvia	79	54	23	1,1	1,1	2,2	0,4	0,4	0,9
Cyprys	143	33	7	0,5	0,3	0,8	0,2	0,1	0,3
Estonia	65	38	14	0,6	0,5	1,2	0,3	0,2	0,5
Malta	143	14	4	0,5	0,3	0,8	0,2	0,1	0,3
Luxembourg	81	22	7	0,5	0,3	0,8	0,2	0,1	0,3
Iceland	6	16	7	0,0	0,0	0,0	0,0	0,0	0,0
TOTAL		**20 867**	**6 966**	**567**	**410**	**976**	**227**	**164**	**391**
ACC4		2437	420	83,8	33,6	117,3	33,5	13,4	46,9
EFTA3		551	237	10,8	10,8	21,6	4,3	4,3	8,6
EU15		15986	5567	420,8	319,7	740,5	168,3	127,9	296,2
NMS10		1894	742	51,2	45,8	97,0	20,5	18,3	38,8
		20867,4	**6966,4**	**566,6**	**409,8**	**976,4**	**226,6**	**163,9**	**390,6**

Not: 70% for the residential sector and 73% for the service sector. (The same saturation levels for all countries are assumed)

Table 8 Estimated saturation of Cooling per country with saturation levels, 40% for the residential sector and 60% for the service sector.

Country	ECI	Total residential area	Total service area	Cooling after saturation			Electricity demand for cooling		
				Residential	Service	Total	Residential	Service	Total
	-	million m2	million m2	TWh	TWh	TWh	TWh	TWh	TWh
Germany	94	3492	1852	48	86	134	19	34	54
Italy	133	2395	453	47	30	76	19	12	31
France	95	2643	861	37	40	77	15	16	31
Spain	147	1885	341	41	25	65	16	10	26
Turkey	135	1542	268	31	18	49	12	7	19
United Kingdom	74	2226	892	24	32	57	10	13	23
Poland	95	802	382	11	18	29	5	7	12
Greece	161	452	149	11	12	23	4	5	9
Romania	137	530	87	11	6	17	4	2	7
Portugal	104	441	126	7	6	13	3	3	5
Netherlands	65	667	183	6	6	12	3	2	5
Hungary	123	310	101	6	6	12	2	2	5
Austria	106	308	119	5	6	11	2	2	4
Belgium	77	416	151	5	6	10	2	2	4
Sweden	73	399	161	4	6	10	2	2	4
Switzerland	85	324	136	4	6	10	2	2	4
Czech Republic	89	333	100	4	4	9	2	2	4
Bulgaria	116	233	31	4,0	1,8	5,8	1,6	0,7	2,3
Slovak republic	117	173	81	3,0	4,6	7,6	1,2	1,9	3,0
Denmark	59	279	114	2,4	3,3	5,7	1,0	1,3	2,3
Finland	72	198	101	2,1	3,6	5,7	0,8	1,4	2,3
Croatia	127	131	33	2,5	2,1	4,5	1,0	0,8	1,8
Norway	67	212	95	2,1	3,1	5,2	0,8	1,3	2,1
Slovenia	127	59	16	2,5	2,1	4,5	1,0	0,8	1,8
Lithuania	85	78	14	1,0	0,6	1,6	0,4	0,2	0,6
Ireland	32	162	58	0,8	0,9	1,7	0,3	0,4	0,7
Latvia	79	54	23	0,6	0,9	1,5	0,2	0,4	0,6
Cyprys	143	33	7	0,3	0,3	0,6	0,1	0,1	0,2
Estonia	65	38	14	0,4	0,4	0,8	0,1	0,2	0,3
Malta	143	14	4	0,3	0,3	0,6	0,1	0,1	0,2
Luxembourg	81	22	7	0,3	0,3	0,5	0,1	0,1	0,2
Iceland	6	16	7	0,0	0,0	0,0	0,0	0,0	0,0
TOTAL		**20 867**	**6 966**	**324**	**337**	**661**	**129**	**135**	**264**
ACC4		2437	420	47,9	27,6	75,5	19,1	11,0	30,2
EFTA3		551	237	6,2	8,9	15,0	2,5	3,5	6,0
EU15		15986	5567	240,5	262,7	503,2	96,2	105,1	201,3
NMS10		1894	742	29,2	37,7	66,9	11,7	15,1	26,8
		20867,4	**6966,4**	**323,7**	**336,9**	**660,6**	**129,5**	**134,7**	**264,2**

Not: The same saturation levels for all countries are assumed

Appendix 2. Electrical power demand of European countries during 2003

Electrical power demand of European countries during 2003

A study of the electrical power demand during 2003 has been done. The annual electrical power demand for 27 European countries has been sorted by size in Figure 18. Behind these annual figures each countries monthly variation can be clarified and give the input for the equation explained previously.

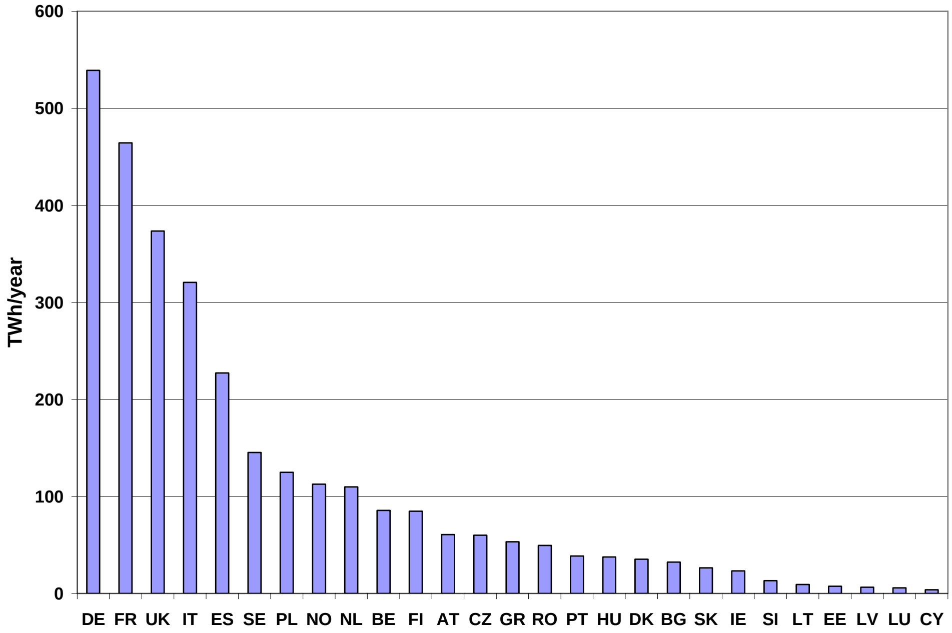


Figure 18 Annual electrical power demands during 2003

The ratio that is defined in Equation 1 is shown in Figure 19. The Mediterranean countries have a high ratio while countries in the northern climate zone have a negative ratio.

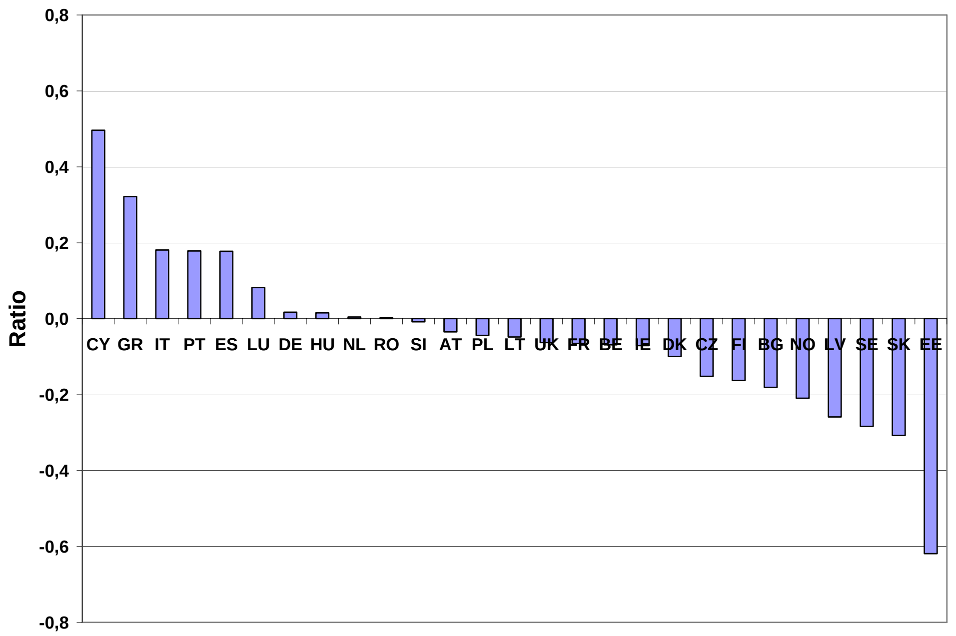


Figure 19 Ratio according to Equation 1 during 2003

The 27 European countries have been grouped in Figure 20 based on their ratio defined in Equation 1. The values in the figure imply that the two groups with medium low to medium high rations (-0.15<Ratio<0.15) stands for the majority of the electricity consumption in Europe.

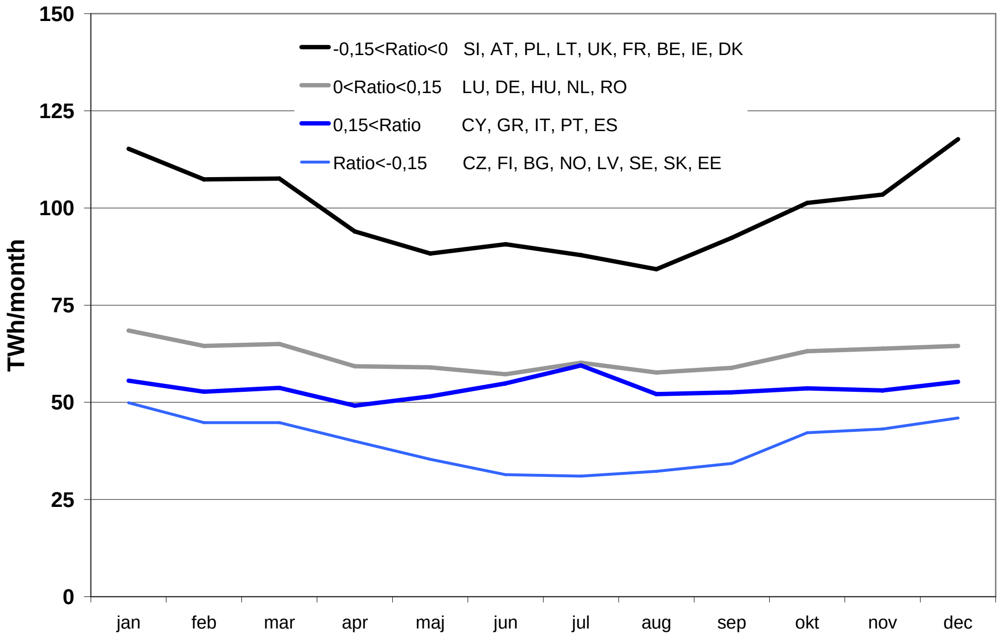


Figure 20 Monthly electrical power demands for groups with high, medium high, medium low and low ratio according to Equation 1.

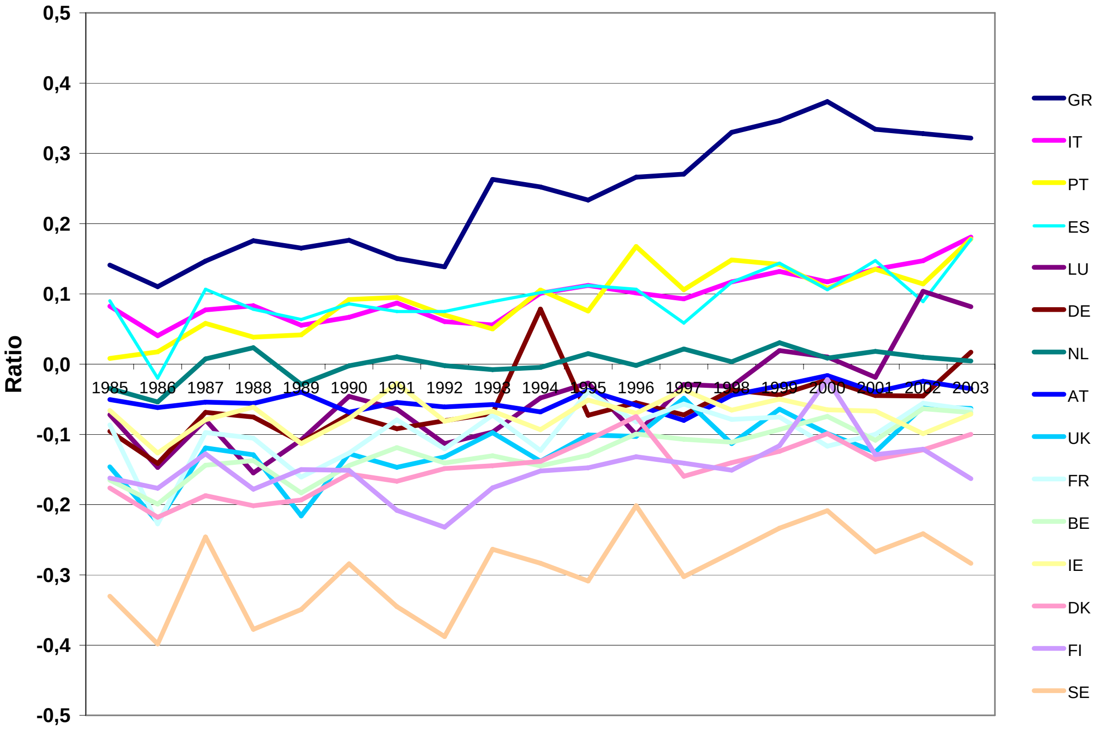


Figure 21 Ratio according to Equation 1 for the EU15 countries

Table 9 Annual electrical energy available to the inland market and Ratio according to Equation 1 for the EU15 countries during the years 1985-2003

TWh/year	AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK
1985	40	53	384	28	117	52	303	26	11	196	4	66	21	130	274
1986	41	54	386	29	120	53	318	27	11	200	4	67	21	128	283
1987	42	57	394	30	124	56	328	28	12	210	4	70	22	137	291
1988	44	59	400	30	130	59	334	31	12	221	4	73	24	138	298
1989	45	60	407	31	136	60	341	32	13	229	4	76	25	139	302
1990	47	63	411	31	141	62	349	32	13	236	4	78	27	140	307
1991	49	65	495	34	146	62	373	33	14	241	4	81	28	141	314
1992	49	67	487	34	149	63	381	35	15	244	4	83	28	139	312
1993	49	68	487	35	148	66	387	36	15	247	4	84	28	141	316
1994	50	71	480	35	152	68	387	37	16	253	5	86	27	138	319
1995	51	74	494	34	158	69	397	39	16	261	5	89	28	142	328
1996	52	75	498	35	165	70	417	40	18	261	5	91	30	141	341
1997	53	77	499	35	171	74	410	43	18	272	5	95	30	142	343
1998	54	79	499	34	181	76	423	44	19	280	5	99	32	143	348
1999	55	80	508	35	192	78	430	45	20	286	6	101	33	143	362
2000	57	83	517	35	202	79	440	49	22	298	6	105	35	147	369
2001	59	84	529	35	211	82	451	51	23	305	5	107	37	150	376
2002	59	84	533	35	213	84	449	53	23	311	6	108	37	149	368
2003	61	86	539	35	227	85	464	53	23	321	6	110	39	145	373

Ratio	AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT	SE	UK
1985	-0,05	-0,17	-0,10	-0,18	0,09	-0,16	-0,09	0,14	-0,07	0,08	-0,07	-0,03	0,01	-0,33	-0,15
1986	-0,06	-0,20	-0,14	-0,22	-0,02	-0,18	-0,23	0,11	-0,13	0,04	-0,15	-0,05	0,02	-0,40	-0,22
1987	-0,05	-0,14	-0,07	-0,19	0,11	-0,13	-0,10	0,15	-0,08	0,08	-0,08	0,01	0,06	-0,25	-0,12
1988	-0,06	-0,14	-0,08	-0,20	0,08	-0,18	-0,11	0,18	-0,06	0,08	-0,15	0,02	0,04	-0,38	-0,13
1989	-0,04	-0,18	-0,11	-0,19	0,06	-0,15	-0,16	0,17	-0,11	0,06	-0,11	-0,03	0,04	-0,35	-0,22
1990	-0,07	-0,14	-0,07	-0,16	0,09	-0,15	-0,13	0,18	-0,08	0,07	-0,05	0,00	0,09	-0,28	-0,13
1991	-0,05	-0,12	-0,09	-0,17	0,07	-0,21	-0,08	0,15	-0,03	0,09	-0,06	0,01	0,10	-0,35	-0,15
1992	-0,06	-0,14	-0,08	-0,15	0,07	-0,23	-0,12	0,14	-0,08	0,06	-0,11	0,00	0,07	-0,39	-0,13
1993	-0,06	-0,13	-0,07	-0,14	0,09	-0,18	-0,07	0,26	-0,07	0,06	-0,10	-0,01	0,05	-0,26	-0,10
1994	-0,07	-0,14	0,08	-0,14	0,10	-0,15	-0,12	0,25	-0,09	0,10	-0,05	0,00	0,11	-0,28	-0,14
1995	-0,04	-0,13	-0,07	-0,11	0,11	-0,15	-0,04	0,23	-0,05	0,11	-0,03	0,01	0,08	-0,31	-0,10
1996	-0,06	-0,10	-0,05	-0,07	0,11	-0,13	-0,08	0,27	-0,07	0,10	-0,10	0,00	0,17	-0,20	-0,10
1997	-0,08	-0,11	-0,07	-0,16	0,06	-0,14	-0,06	0,27	-0,04	0,09	-0,03	0,02	0,11	-0,30	-0,05
1998	-0,04	-0,11	-0,04	-0,14	0,12	-0,15	-0,08	0,33	-0,07	0,12	-0,03	0,00	0,15	-0,27	-0,11
1999	-0,03	-0,09	-0,04	-0,12	0,14	-0,12	-0,08	0,35	-0,05	0,13	0,02	0,03	0,14	-0,23	-0,06
2000	-0,02	-0,07	-0,02	-0,10	0,11	-0,02	-0,12	0,37	-0,06	0,12	0,01	0,01	0,11	-0,21	-0,10
2001	-0,04	-0,11	-0,04	-0,14	0,15	-0,13	-0,10	0,33	-0,07	0,14	-0,02	0,02	0,14	-0,27	-0,13
2002	-0,02	-0,06	-0,05	-0,12	0,09	-0,12	-0,06	0,33	-0,10	0,15	0,10	0,01	0,11	-0,24	-0,06
2003	-0,04	-0,07	0,02	-0,10	0,18	-0,16	-0,06	0,32	-0,07	0,18	0,08	0,00	0,18	-0,28	-0,06

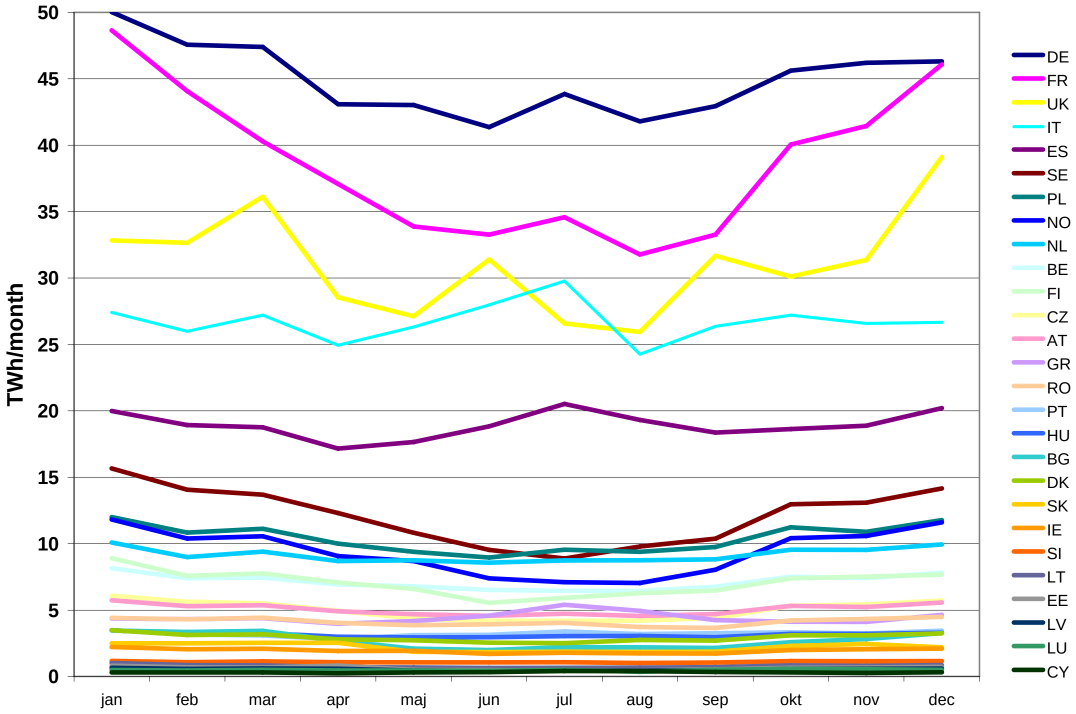


Figure 22 Monthly electrical demands during 2003

Table 10 Electrical demand and ratio according to Equation 1 for 2003

GWh/month	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	NL	NO	PL	PT	RO	SE	SI	SK	UK
jan	5 734	8 144	3 457	307	6 081	50 021	3 478	814	19 992	8 901	48 643	4 363	3 478	2 219	27 407	1 011	485	658	10 085	11 818	12 004	3 483	4 414	15 665	1 170	2 501	32 833
feb	5 294	7 397	3 357	306	5 628	47 558	3 127	694	18 926	7 580	44 072	4 319	3 183	2 049	25 984	860	452	565	8 996	10 392	10 832	3 177	4 307	14 066	1 073	2 491	32 648
mar	5 359	7 443	3 429	309	5 509	47 402	3 166	679	18 755	7 766	40 283	4 385	3 273	2 092	27 203	832	499	602	9 397	10 551	11 121	3 091	4 422	13 683	1 135	2 534	36 128
apr	4 899	6 937	2 693	250	4 938	43 087	2 798	825	17 156	7 070	37 089	3 970	2 990	1 919	24 937	696	454	573	8 688	9 060	9 999	2 811	4 036	12 311	1 081	2 538	28 542
maj	4 691	6 787	2 104	297	4 354	43 021	2 728	494	17 653	6 593	33 879	4 168	2 942	1 928	26 314	674	445	455	8 749	8 687	9 387	3 109	3 856	10 814	1 064	1 857	27 125
jun	4 572	6 524	1 989	327	4 195	41 360	2 548	474	18 825	5 549	33 264	4 581	2 951	1 707	27 984	641	419	410	8 569	7 386	8 960	3 134	3 932	9 531	1 062	1 830	31 402
jul	4 722	6 446	2 207	408	4 179	43 857	2 505	440	20 521	5 920	34 574	5 397	3 038	1 781	29 770	659	493	436	8 730	7 094	9 540	3 385	4 045	8 876	1 072	1 864	26 585
aug	4 556	6 435	2 197	397	4 211	41 795	2 749	468	19 315	6 267	31 776	4 941	3 055	1 734	24 259	668	349	439	8 758	7 046	9 391	3 191	3 725	9 785	1 014	1 848	25 944
sep	4 708	6 757	2 149	338	4 395	42 945	2 701	531	18 371	6 474	33 263	4 236	2 953	1 726	26 355	698	512	471	8 828	8 031	9 756	3 253	3 655	10 369	1 049	1 865	31 678
okt	5 315	7 527	2 577	298	5 321	45 605	3 106	649	18 620	7 394	40 051	4 120	3 215	1 995	27 201	841	566	569	9 545	10 406	11 229	3 326	4 222	12 967	1 158	2 303	30 107
nov	5 238	7 410	2 824	266	5 423	46 208	3 099	674	18 880	7 522	41 450	4 107	3 206	2 046	26 582	803	547	578	9 527	10 578	10 893	3 233	4 325	13 087	1 148	2 444	31 362
dec	5 571	7 808	3 270	318	5 722	46 305	3 241	722	20 209	7 667	46 080	4 638	3 289	2 099	26 664	859	500	597	9 940	11 610	11 770	3 450	4 479	14 162	1 167	2 198	39 108
TWh/year	**61**	**86**	**32**	**4**	**60**	**539**	**35**	**7**	**227**	**85**	**464**	**53**	**38**	**23**	**321**	**9**	**6**	**6**	**110**	**113**	**125**	**39**	**49**	**145**	**13**	**26**	**373**
Ratio	**-0,04**	**-0,07**	**-0,18**	**0,50**	**-0,15**	**0,02**	**-0,10**	**-0,62**	**0,18**	**-0,16**	**-0,06**	**0,32**	**0,02**	**-0,07**	**0,18**	**-0,05**	**0,08**	**-0,26**	**0,00**	**-0,21**	**-0,04**	**0,18**	**0,00**	**-0,28**	**-0,01**	**-0,31**	**-0,06**