10th International Symposium on District Heating and Cooling

September 3-5, 2006

Monday, 4 September 2006

Sektion 4 a

Effects on DH from directives, laws and regulations

The new European heating index

S. Werner,
Chalmers University of Technology, Göteborg/Sweden

The New European Heating Index

Sven Werner
sven.werner@fvb.se
tel +46 35 173592

Department of Energy and Environment
Division of Energy Conversion
Chalmers University of Technology
SE- 412 96 Göteborg, Sweden

Abstract

A new European heating index (EHI) has been elaborated and introduced in order to explain the geographical distribution of the average specific space heating demands in Europe with respect to climatological influences. The European heating index was elaborated within Work Package 1 within Ecoheatcool, a project during 2005 and 2006 within the intelligent energy for Europe (IEE) program and coordinated by Euroheat & Power. A corresponding cooling index has also been elaborated within the Ecoheatcool project.

The paper contains the fundamental background for the heating index, the construction procedure, and a map of Europe with this index. The index is based on climatological information and the ideal optimal space heat demand based on the optimal insulation thickness.

The conclusions from the analysis of this new heating index are:

- The heating index is proportional to the square root of the degree-day number
- A moderate variation of the national residential space heating demands in Europe appears from climatological point of view, since only half of the existing variation can be explained by climatological influences.
- Actual residential heat demands have a significant variation due to variations in heat costs, indoor temperatures, hot water consumption, and affordability.

Introduction

European heat markets are still national and local in contrast to the electricity and gas markets, which have become more integrated from the introduction of the first and second generation of the European electricity and gas market directives. The national heat markets are less integrated and not harmonised. Very little aggregated information is available about the heat markets on a European level. With respect to new initiatives for more renewable energy and lower carbon dioxide emissions, more information is demanded about the existing national heat markets.

In order to get a proper overview of the European heat markets, a heating index have been elaborated in order to explain the climatological background for space heating. This background must be defined in order to identify other factors influencing the space heating demands in Europe. The space heat demands depend on the local difference between indoor and outdoor temperatures, insulating properties, air change rates, building sizes, solar and internal gains, and wind chill from increased air changes. These influencing parameters give a large variation of European space heat demands. In order to understand all various influences, a demand appear to separate the climatological influences in the space heating demand.

The Degree-Day Concept

The idea of creating an annual accumulated sum describing the local temperature conditions for a location was put forward in the 19th century, but it was first used for agricultural purposes. Several heating engineers in different countries suggested the use for space heating in the early 20th century. The method was commercially introduced in the USA during the 1920’s and called the “degree-day”-method. It was used for checking heating plant operation and predicting fuel consumption. The American concept was brought to Europe in 1927 by Erich Schulz, a district heating engineer at Bewag in Berlin, (Werner, 1984). Both the American and European use expanded in the 1930’s and several degree-day handbooks were published.

The degree-day method just sum up all daily temperature differences between an effective indoor temperature and the daily average outdoor temperature for a location, if the outdoor temperature is lower than a specified limit temperature (threshold value). The effective indoor temperature is some degrees lower than the actual indoor temperature in order to compensate for internal temperature gains from human metabolism and indoor electricity use. The limit temperature is some degrees lower than the effective indoor temperature in order to compensate for solar gain during late spring and early autumn. The lower the limit temperature is, the shorter the heating season will be. Figure 1 shows a map of Europe with the degree-day number estimated with an effective indoor temperature of 17ºC and a limit temperature of 13ºC.

The degree-day method is used (and misused) in most European countries. This method is not harmonised in Europe, since each country has its own standard computation. However, a complete harmonisation is difficult to perform, since the magnitudes of the effective indoor and limit temperatures depend on how well the buildings are insulated, which vary significantly throughout Europe.

The purport with the degree-day number is simply to estimate “the amount of cold to counteract with space heating” on a certain location. As a method, it is very simple and rough, and most suitable for large aggregated building volumes and for annual adjustments of heat demands. It cannot directly be used to explain how the space heating demands vary from south to north in Europe, since the actual demands also depend on how well the buildings are insulated. In both (Enerdata, 2003) and (IEA, 2004), space heating demands per degree-day are presented for various countries. That kind of analysis presume that the same building, with the same degree of insulation, exist in both Palermo in Southern Italy and Kiruna in Northern Sweden. According to Figure 1, the degree-day number is more than ten times higher in Kiruna than in Palermo. But the heat demand in Kiruna is not ten times higher, since the buildings are better insulated.

It would be much better if a heating index could include an average rational use of heat resistance in buildings. The degree-day method does not consider the rational use of heat with respect to insulation. Therefore, the degree-days should not be used in analyses of national residential heat demands as in (Enerdata, 2003) and (IEA, 2004).

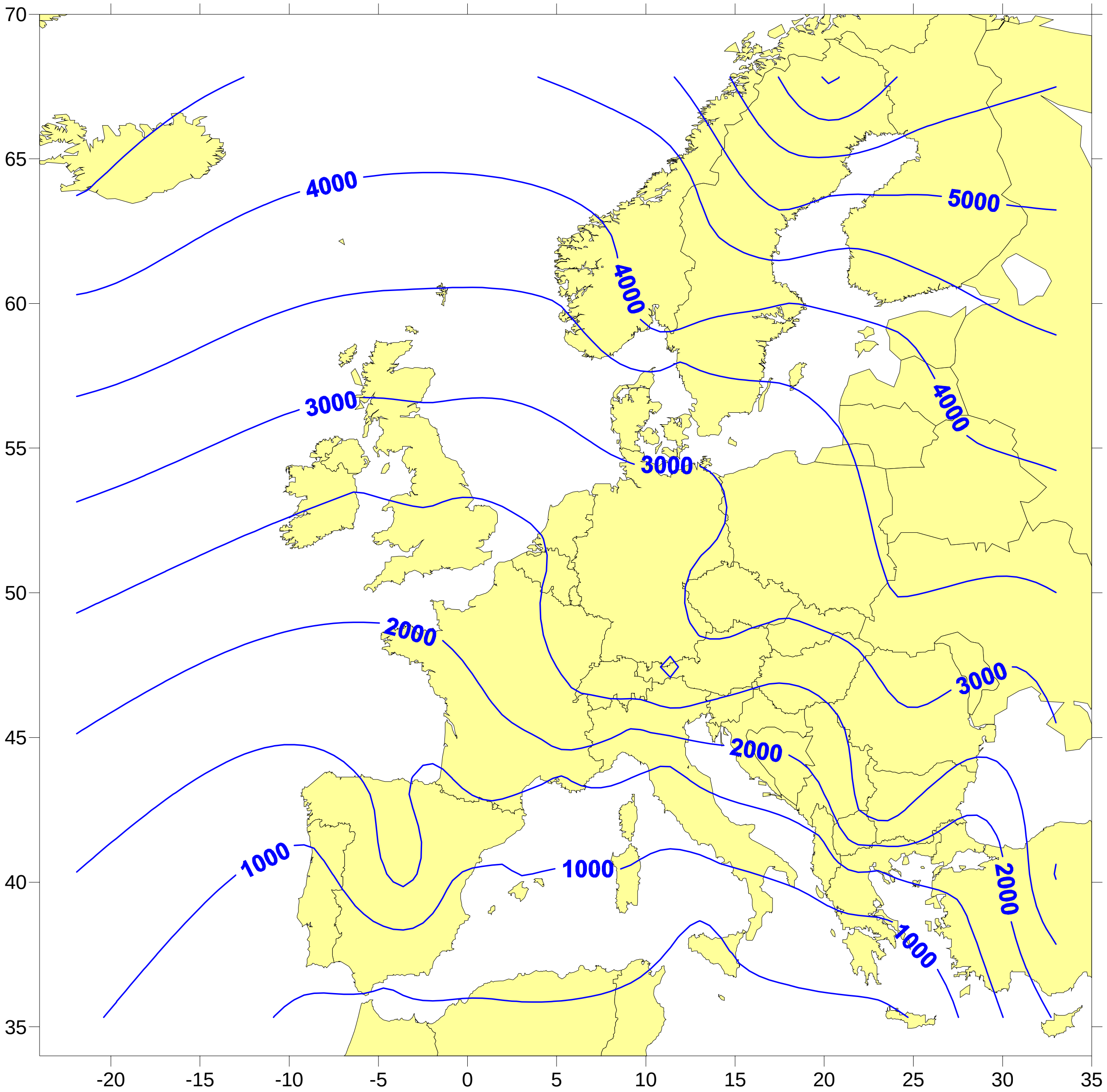

Figure 1. Degree-days estimated for various urban locations in Europe. The number of degree-days has been estimated according to a 17/13-system explained in the text. Note that the map is not representative for all locations in each country, since the existing data grid consists of only 80 locations.

Optimal Space Heat Demand from Optimal Heat Insulation

The optimal insulation thickness t_{opt} can be estimated from an optimisation analysis of the heat flow through an insulated wall with respect to prevailing costs and insulating properties:

$$t_{opt} = \sqrt{G * k_q * \lambda / (a * k_t)} \qquad [m]$$

where
G = degree-time integral in Ks (24*3600*Degree-days), based on a chosen indoor temperature
k_q = heat cost (EUR/J)
λ = heat conductivity for the insulation, W/mK
a = annuity, from interest rate and economic lifetime
k_t = effective cost for insulation volume, EUR/m^3

The annual specific optimal space heat demand q_{opt} for a building is

$$q_{opt} = Q_{opt}/A = G * \lambda / t_{opt} \qquad [J/m^2]$$

where
A = surrounding surface, m^2

By combining these two expressions, one get finally:

$$q_{opt} = \sqrt{G * a * k_t * \lambda / k_q} \qquad [J/m^2]$$

Hence,

The optimal heat demand is then proportional to the square root of

- the degree-day number
- the insulation cost
- the annuity
- the heat conductivity for the insulation
- the inverse of the heat cost, giving the ideal price elasticity of –0,5

The conclusion from this short analysis is that the long-term optimal insulation thickness is proportional to the square root of the 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 optimal heat use for space heating should be proportional to the square root of the degree-day number, since the overall building heat resistance should be proportional to the square root of the degree-day number. It is therefore possible to create an index that explains the expected space heating demand at a uniform heat and construction cost and a uniform indoor temperature, when the degree-day number is different for different locations.

The New European Heating Index

A new European heating index (EHI) has been elaborated in (Ecoheatcool, 2005a), according to the simple analysis performed above, and is presented in figure 2 and in Table 1.

The index is normalised, where 100 is equal to an average European condition. Using a European reference degree-day number of 2600, corresponding to an annual average outdoor temperature just above 10ºC, fulfils this normalisation. The following standard components have been used for the European reference degree-day number:

- Indoor temperature: 20°C
- Indoor temperature addition from internal gains (indoor electricity use and human metabolism): 3°C
- Indoor temperature addition from solar gains and start-up tolerance at heating season start and end: 4°C

This gives the European reference values of

- The effective indoor temperature: 17°C
- The limit outdoor temperature: 13°C

The solar and internal gains are then adjusted for each location by the square root of the degree-day number, since both these gains are more valuable in indoor temperature addition when a building is well insulated. Hereby, the effective indoor temperatures are lower in Northern Europe and higher in Southern Europe. Other effective indoor temperature affects also the limit temperature by using a constant solar gain. Hereby, the limit temperatures are lower in Northern Europe than in Southern Europe.

The used simplifications for the new heating 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. Elimination of these simplifications can of course refine the index, but it would be a pedagogic value to keep it simple.

The same methodology has been used for creating a new cooling index for Europe (ECI) and this index is presented in the cooling market report from the Ecoheatcool project (Ecoheatcool, 2005b).

Figure 2 shows that the climatological heat demands for space heating should not vary very much. Manchester, Brussels, Strasbourg, Budapest, Sofia, and Odessa are the typical space heating cities in Europe, having a heating index of near 100. The space heat demand in Stockholm should only be 20 % higher than the space heat demand in Brussels. Florence should have a 20 % lower space heat demand than Budapest. Hamburg and Bucharest should have the same space heat demands. Kiruna should have 2,8 times (151/54) higher heat demand than Palermo.

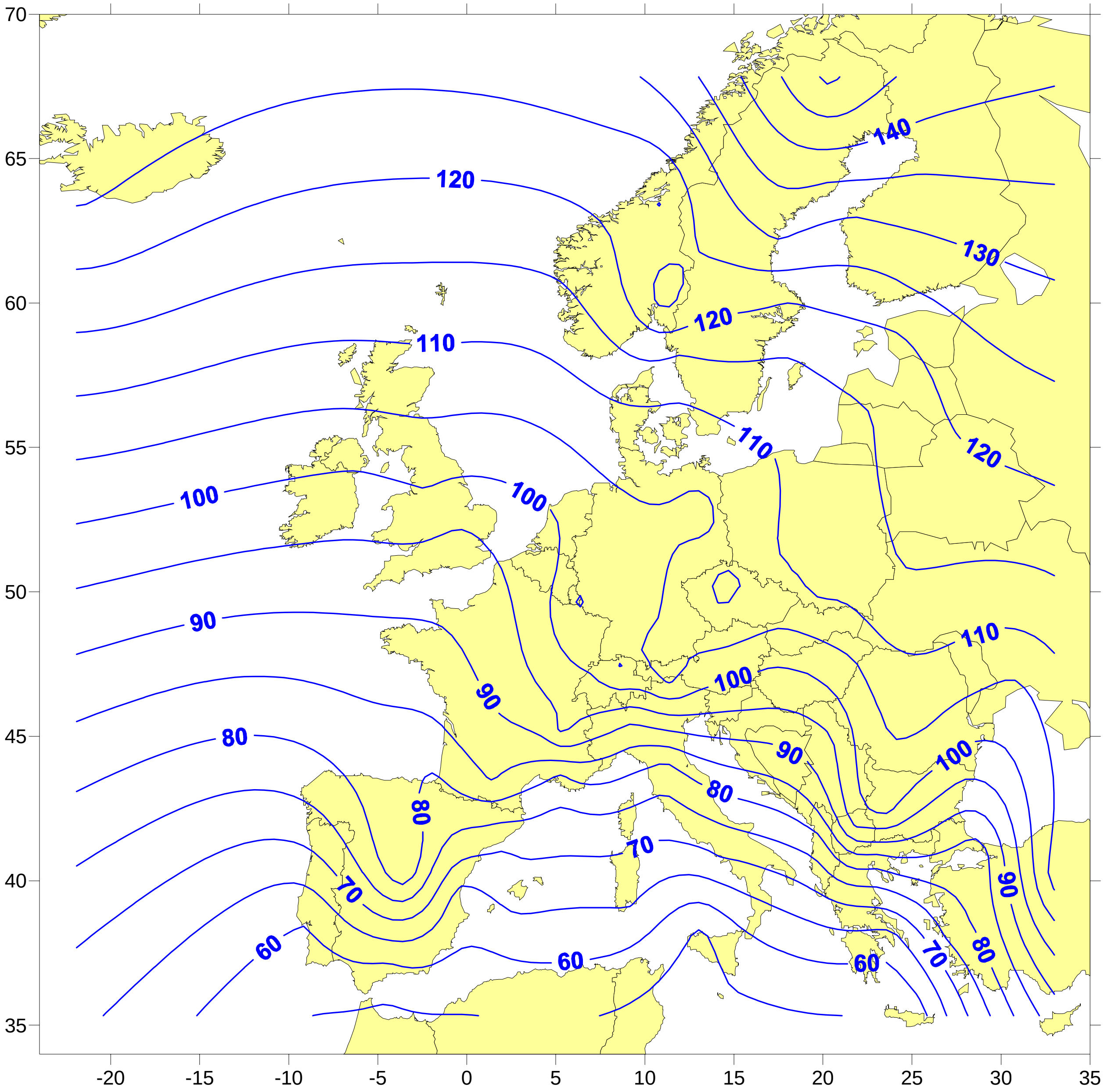

Figure 2. The new European heating index (EHI) in a contour map computed from information for 80 urban locations in Europe. The space heating demand should be proportional to this index. Note that the map is not representative for all locations in each country, since the existing data grid consists of only 80 locations.

Table 1. The European heating index estimated for 80 locations

Location	EHI	Location	EHI
Aberdeen	107,6	Manchester	99,6
Amsterdam	99,2	Marseille	77,9
Ankara	107,3	Milano	89,5
Aten	62,3	Minsk	118,8
Barcelona	70,5	München	104,7
Belgrad	94,2	Nantes	87,6
Bergen	114,1	Napoli	70,3
Berlin	103,5	Odessa	103,3
Bordeaux	85,0	Oslo	127,5
Bratislava	102,5	Oulu	136,2
Brno	107,6	Palermo	54,0
Brussels	98,1	Palma	67,5
Budapest	100,9	Paris	94,1
Bukarest	102,8	Porto	70,7
Cagliari	65,7	Prague	111,5
Chisinau	106,1	Reykjavik	126,7
Debrecen	104,1	Riga	115,7
Dublin	98,2	Roma	72,2
Firenze	77,5	San Sebastian	78,5
Frankfurt am Main	101,2	Skopje	96,0
Grenoble	97,4	Sofia	103,4
Göteborg	112,6	Stockholm	117,2
Hamburg	105,6	Strasbourg	100,0
Helsinki	124,6	Sundsvall	131,4
Heraklion	56,9	Tallinn	121,3
Innsbruck	108,6	Thessaloniki	80,4
Istanbul	82,4	Tirana	78,0
Izmir	77,1	Toulouse	85,9
Kiev	113,8	Trondheim	119,7
Kiruna	151,2	Umeå	133,4
Krakow	111,0	Valencia	63,1
Köbenhavn	108,4	Valletta	54,5
Leba	110,2	Varna	93,5
Lisboa	60,5	Warszawa	111,4
London	92,9	Vasa	130,1
Luxembourg	106,0	Wien	103,0
Lviv	114,1	Vilnius	118,3
Lyon	94,3	Zagreb	94,6
Madrid	85,7	Zürich	105,3
Malaga	57,2	Ålborg	111,7

Correlation between residential heat demands and the new EHI

The correlation between the actual 2003 specific residential heat demands and the new European heating index (EHI) are presented in Figure 3 for various European countries. The national specific residential heat demands have been estimated by the ratio of all residential heat demands and the corresponding floor space of all residential buildings. The national residential heat demands have been estimated the from all final residential energy consumption in the IEA energy balances (IEA, 2005) and some standard conversion efficiencies when fuels are used for local conversion to heat. Estimates are published in (Ecoheatcool, 2005a). The national residential floor spaces have been retrieved from (Boverket, 2005). Each capital was chosen as the typical climatological location for each country, since the capital area dominate the population in most countries.

National averages of residential heat demands are scattered in Figure 3 around the EU15 average line, equal to direct proportionality to the effective demand average of 599 MJ/m^2 and the effective EHI average of 94,8 for EU15.

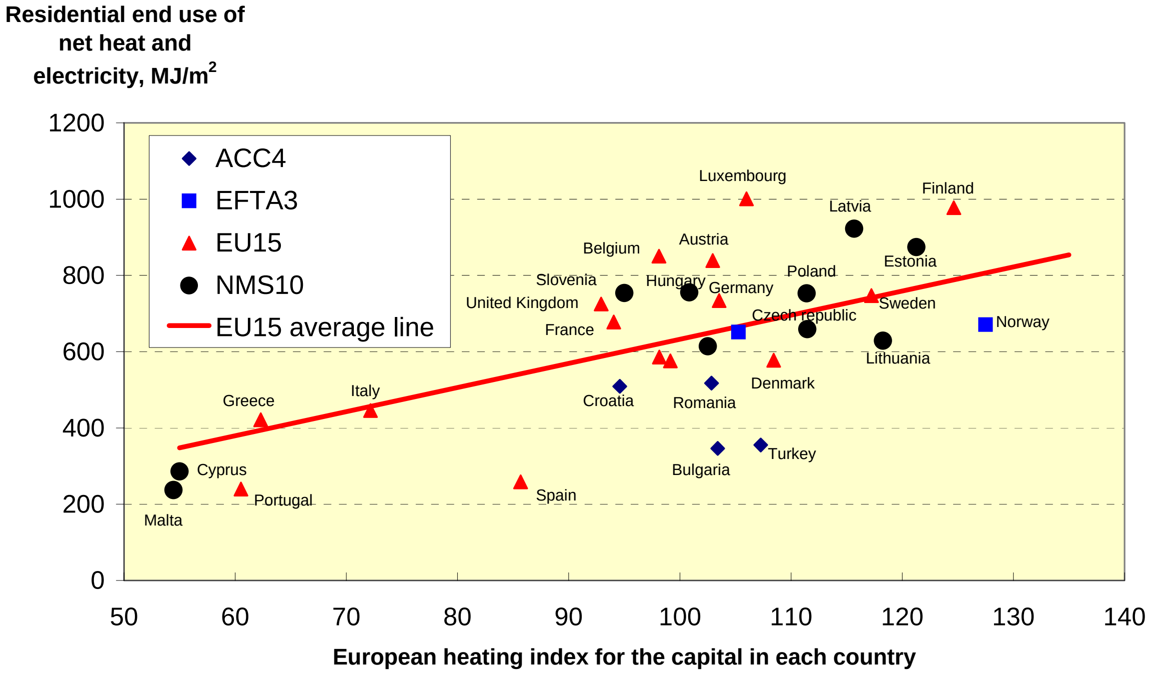

Figure 3. Correlation between the residential net heat and electricity use per m^2 during 2003 and the new European heating index. Iceland has been excluded due to a high value (1750 MJ/m^2).

The EHI presumes uniform indoor temperature, uniform heat cost, uniform heat resistance cost, and no hot water consumption. Furthermore, an economic rationality is expected with respect to the use of heat resistance and a normal affordability for heat use is presumed. Actual deviation from a national average of EHI in Figure 3 can be explained by these factors. Countries with high indoor temperatures, high heat resistance cost, low heat cost, high hot water consumption, lower heat resistances and high affordability will appear above the average line, and vice versa. Countries with many buildings lacking heating systems will also appear below the average line.

Countries located near to the EU15 average line are Greece, Italy, Ireland, Netherlands, Slovak republic, Switzerland, Czech republic, and Sweden. They have all an average residential net heat and electricity use with respect to their climatic location. Located above the average line, United Kingdom, Slovenia, Belgium, Austria, Latvia, and Finland are countries with high residential heat demands. Located below the average line, Denmark is often referred to as a country with progressive heat resistance legislation. Malta, Portugal, Spain, Bulgaria, and Turkey are known to have large fractions of no heating systems in residential buildings. Low position for Turkey, Bulgaria, Romania, Croatia can also depend on low indoor temperatures during the heating season.

For Northern, Central, Western, and Eastern Europe, the heat demands seems to be about the same despite climatic location. No major difference can be identified between EU15 and NMS10 countries at the same heating index. Only Mediterranean and Accession countries have significant lower heat demands. A simple correlation analysis reveals that the European heating index can only explain 49 % of the variations in residential heat demands in 31 European countries (Iceland excluded due to high estimate). Hereby, other influences as heat costs, hot water consumption, indoor temperatures, and affordability can explain the other half of all variations.

Possible sources for errors in this analysis are

- Improper allocation of energy use between the residential and service sectors in the IEA energy balances
- The capital is not the proper heat demand average in each country (as for Spain and Turkey)
- The definitions of residential floor areas are not harmonised among the countries analysed
- Simple standard conversion efficiencies were used for the heat demand estimations when fuels were used for heating.

Conclusions

The new European heating index has shown that the expected variation of space heating demands is not dominating among the European countries analysed. Heat demands in Western, Central, and Eastern Europe should not be so much lower than heat demands in the Nordic and Baltic countries with respect to climatological influences. Only half of the existing variations in residential heat demands can be explained by climatological influences. The other half of the existing variations should be explained by variations in indoor temperatures, hot water consumption, heat costs, and affordability for heating.

Acknowledgment

The European heating index was elaborated within Work Package 1 within ECOHEATCOOL, a project during 2005 and 2006 financed by Euroheat & Power and the Intelligent Energy for Europe (IEE) program. More information about this project is available at www.ecoheatcool.org

References

Boverket (the Swedish National Board of Housing, Building, and Planning), 2005, Housing Statistics in the European Union 2004. Karlskrona.

Ecoheatcool, 2005a, The European heat market. Euroheat & Power, Brussels. Available at www.ecoheatcool.org

Ecoheatcool, 2005b, The European cooling market. Euroheat & Power, Brussels. Available at www.ecoheatcool.org

Enerdata, 2003, Energy Efficiency in the European Union 1990-2001. Save-ODYSSEE project on Energy Efficiency Indicators.

IEA, 2004, 30 years of energy use in IEA countries. International Energy Agency, Paris.

IEA, 2005. Energy balances for OECD and non-OECD countries. Paris.

Werner, S, 1984, The heat load in district heating systems. Dissertation. Chalmers University of Technology, Göteborg.