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COMMENTS ON PROPOSED CHANGE OF CLIMATIC CORRECTION IN THE ODYSSEE PROJECT

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Summary

It has been suggested in the ODYSSEE Project to use a new method to correct for climatic differences. Nowadays degree-days are used linearly, and the new proposition is to use the square root of degree-days (so-called Werner method) in climatic corrections. The objective of this analysis was to investigate which is more correct in country comparisons. One of the drawbacks of the suggested Werner method is that it is based on costs. Cost should not be a part of how specific energy consumption is measured. Costs can be used to explain resulting differences, but then the Werner method should extended to all cost factors, not only the insulation thickness.

The square root method gives results which suggest that the buildings in southern Europe are more energy efficient than those in the northern Europe at identical climate conditions which is not conceivable given the building characteristics. This is also in contradiction with the main assumptions of Werner's study.

Heating energy consumption is proportional to the degree-days, not the square root of degree-day. A method based on the square root is therefore physically incorrect, if it is used to climatic correction of heating energy. Also as seen by the test, it does not improve the smoothness of the climatic corrections for individual countries.

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Preface

This study is made to help to form a national position to ODYSSEE project's suggestion of changing the way how to normalize heating energy. ODYSSEE's Finnish partner, Motiva Oy, approached the author, who is familiar with ODYSSEE and has done preliminary studies on degree-days as used in ODYSSEE already earlier, on this subject.

The results of this study will hopefully be useful for Motiva Oy in forming a national opinion and otherwise in EU collaborations.

The author thanks Lea Gynther, the main contact person, as well as Ulla Suomi and Saara Elväs at Motiva for this opportunity, their valuable input, and for the friendly cooperation during this study and earlier.

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Göran Koreneff

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1 Introduction

It has been suggested in the ODYSSEE project in the EU's Intelligent Energy for Europe Programme (IEE) that a new method to correct for climatic differences should be implemented. Nowadays degree-days are used linearly, and the new proposition is to use the square root of degree-days in climatic corrections. The background to the suggestion is a presentation by professor Sven Werner (Chalmers University), The New European Heating Index, held at 10th District Heating and Cooling Symposium, Hanover, September 4-5, 2006, according to which

- "The heating index is proportional to the square root of the degree-day number."
- "The index is based on climatological information and the ideal optimal space heat demand based on the optimal insulation thickness."

This presentation itself was a result of Work Package 1 within Ecoheatcool, a project implemented during 2005 and 2006 within the IEE Programme. The project was coordinated by Euroheat & Power.

A presentation held at the ODYSSEE project meeting in Warsaw in October 2011 of the effects of the new way to use degree-days for normalizing is also used as input material for this study.

2 Goal

The target of this paper is to give a short briefing of the advisability of changing the country comparison methodology to the form suggested by Prof. Werner's presentation, and what effects it would have from a Finnish point of view. The main question is, is the proposed way to normalize different countries' heating energies correct and fair from Finnish or EU perspective?

3 Basic ponderings on the core of temperature corrections

The heat losses in a house are proportional to the temperature difference between indoors and outdoors, not square root proportional. That is the basic assumption even behind the new suggestion from prof. Werner.

It would be easier to correct heat <u>losses</u> than heat demand, although measuring losses is not practical. To assess the temperature effect of different years on heat losses, we would sum the temperature difference between indoors and outdoors for those hours that it's colder outdoors than indoors and use it in comparison to a normal temperature year. Here heat losses are assumed to start immediately when it's colder outdoors than indoors. If an insulation improvement is made, we get smaller losses, but the same temperature difference measurements could still be used to perfectly normalize the losses, see fig. 1.

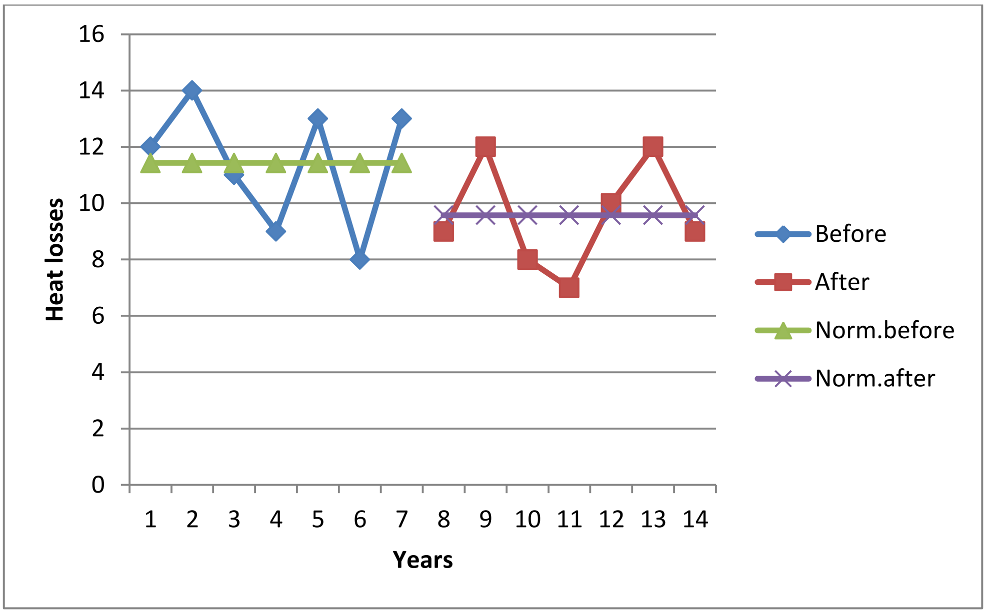

Fig. 1. Theoretical normalized heat losses for a house before and after an insulations improvement. The house is assumed to be shielded from the sun.

However, we are usually not interested in heat losses *per se*, but in the need for heating from external sources. In reality, we have internal (humans and appliances) and external (sun radiation) heat sources. The heating system is used when these are not enough to keep the indoor temperature at desired level. In addition, the heating system might be manually switched off for the summer, so that it will not start even if the temperatures are falling.

There are three variables to consider: what is the desired indoor temperature, how much internal heat sources are there, and when does the heating system start.

1. For the desired indoor temperature and the internal heat sources we can use a combined parameter, the effective indoor temperature. The heating system only needs to heat up the space to the effective temperature, for example 17 °C, after which the internal heat sources and the sun will raise the temperature to the desired indoor level.
2. We can use a threshold outdoor temperature for when the heating starts. The assumption is that when temperatures are quite high, also the sun will have a strong heating influence, so that heating will not be needed at 17°C, but only under a lower threshold of, e.g., 13°C. In countries with poorly insulated houses, the threshold is often higher. Fully harmonised calculation methods, such as Eurostat’s method using a uniform threshold of 15°C do not take into account these differences in heating needs.

These two variables are, however, not similar everywhere. The sun’s heating value is higher in the south than in the north. A plausible assumption is that it could give at least one or two degrees extra heat in the winter in the south, whereas it never shines in the north. The sun is warmer in the south also during the transition periods. Reference data on the heating effect of the sun exist.

In normal energy efficiency comparisons external factors, such as temperature and the impact of sun radiation, are eliminated but all energy efficiency measures, such as insulation thickness, are taken into account. The Werner method suggests otherwise.

Energy efficiency measures are, for example, improved insulations, added/improved heat recovery, behavioural changes such as lowering indoor temperature, or starting heating later in the year. Changes in these should be seen in the parameter for useful heating. [1]

4 The different applications for temperature corrections

4.1 Use no. 1

Usage: To normalize measured heating energies for a selected house to the location's standard temperature.

Motivation: To estimate changes in heat demand that are not dependent on the stochastic outside temperature, for example to assess energy efficiency improvements such as better insulation, heat recovery, behavioural changes, or to become aware of new heat leakages. Also a planning tool to assess expected heating demand of houses to be built.

What do we need: We need either a standard or a fixed way to calculate the degree-days, so that changes from one year to the next can be seen directly, or we need changing references. For example, if we drop our indoor temperature setting from one year to the next, this should show up as an energy efficiency improvement. Using a constant reference degree-day, it does. The other solution is to change the degree-day formula by dropping the effective indoor temperature, and in that case we must also change the reference degree day to the new normalized average, see second average of normalized values in fig. 1.

Practical issues: Because there are no household level degree-day measurements, only area dependent, we cannot have individual degree-day settings. That means that we use a standard method to calculate degree-days.

Cons: For a single household, the standard method does not take into account energy efficiency measures done in the house that lower the actual effective indoor temperature. This results in an under-correction[2] of the heating of that house, see fig. 2, and a modulating normalized curve instead of a straight horizontal one.

[1] For final energy use for space heating, changes in heat production are an additional factor. However, because of the differing primary energy factors, it is a much more complex issue if we want to see the real efficiency improvements from a holistic perspective. Decomposition analyses could be a suitable tool for that.

[2] There is under-correction because the efficiency improvement in reality lowers the effective indoor temperature. The real degree day (dd) and ref. dd for that house should thus be lower, giving annual dd differences a stronger impact. For example: dd.ref=6000, dd=5500 => quotient 6000/5500= 1.09, but using "real" degree-days: dd.ref=5500, dd=5000 => quotient 5500/5000= 1.10. The error is 1% in the normalized useful heat value, and that is already noticeable in energy efficiency calculations.

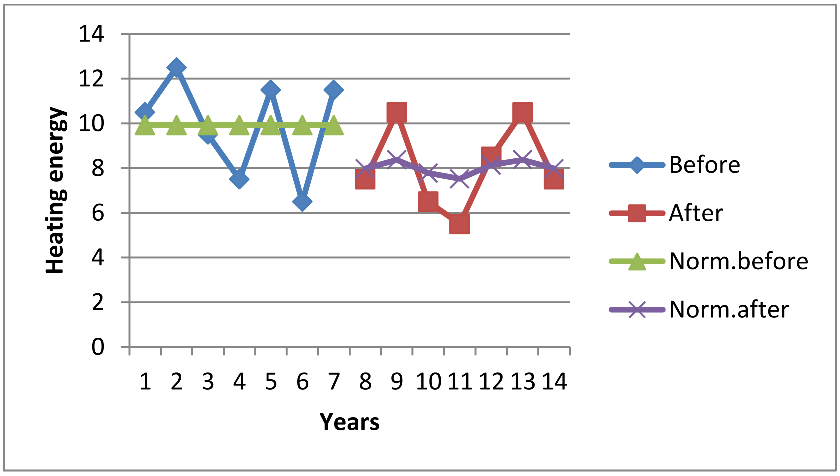

Fig. 2. Undercorrected normalized heating demands after an energy efficiency improvement measure.

Of course, if we change the way degree-days are calculated once in a while, but do not recalculate historical degree-days but use them as such, it hides the effects of the energy efficiency improvements. For example, in fig. 3, the effective indoor temperature of the degree-days formula has been changed twice with time to match improved insulations levels etc. for the red curve. As can be seen, the 30% reduction of the heating needs 1940-2010 due to constant efficiency improvements is not to be seen anymore, if we mix different degree-day calculation results.

Conclusions: The degree-day definitions (effective indoor temperature etc.) should be as correct as possible to avoid undue modulations in the climatic corrections.

The degree-day definition should be constant over the whole time span under scrutiny, and also used for the reference degree-day. The reference degree-day should also be constant over the whole time span under scrutiny.

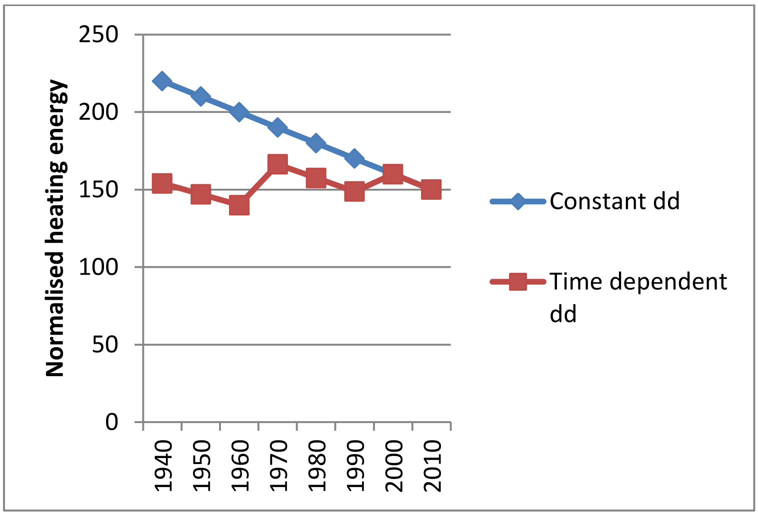

Fig. 3. The effective indoor temperature is either constant or changes with time in the calculation of the degree-days. The outdoor temperature in the figure is constant over time.

4.2 Use no. 2

Usage:	To normalize measured heating energies for a selected country.
Motivation:	To estimate changes in heat demand which are not dependent on the stochastic outside temperature, for example, in the assessment of energy efficiency improvements.
Methodology:	To use degree-days of a country. As in use no. 1, we should use a as representative definition of degree-days as possible for that country. For example, the selected effective indoor temperature should be one that best represents the country’s insulations, solar radiation etc. levels. The target is to have as a result as straight horizontal line as possible for the normalized national heating demands. Any deviations from the line could then directly be seen as efficiency improvements or impairments.
Restrictions:	This method is targeted at monitoring the heat demand development for a specific country. The degree-days in use encompass all the energy efficiency improvements done up-to-date in that country. The target is to have it as exact as possible for the given country, which means that it is not well suited for country comparisons. The country-specific degree-days are themselves measurements of the level of energy efficiency, as described in the methodology. Using the country-specific degree-days for climatic corrections to a European average temperature hides all the energy effectiveness measure already inherent in them from one country to the next.
Cons:	If we want to compare backwards in time, we have to recalculate the historical degree-days using the current formula for calculating degree-days (see constant dd in fig. 3).

4.3 Use no. 3

Usage: To compare the heating demands between different countries.

Motivation: To get a picture of the energy efficiency levels of different countries compared to each other.

Methodology: The same method needs to be used to calculate degree-days in each country.

If we, for example, have two countries with the same heat demand and the outside temperature, but one calculates degree-days with an effective indoor temperature of 17°C and the other with 18°C, and their heating energies are then converted to average European degree-days, one may be seen as efficient and the other as inefficient.[3]

Therefore for comparison purposes, either the European median/average temperature time series should be used as input for national degree-day calculations, or all should use the same comparison degree-day calculation formula.

If there are other national differences in how to calculate the degree-days, for example, if heating system are assumed to be closed down during the thermal summer, the differences should be removed from the calculations of the degree-days used in the comparisons. It is an energy efficiency measure, for example, to shut down heating altogether during the summer. Another energy efficiency measure would be to use room-wise heating control so that not all rooms are heated similarly during the winter. Not having central heating could thus be seen as an energy efficiency choice. The proportion of central heating could, however, be used to clarify differences between countries (as is often done).

Restrictions: Economical optimisation should have no bearing on the heating energy comparison between countries.

Economic issues can be used for explaining the differences, for example, the variable cost for creating one heat unit, the GDP/person, PPP, etc.

Cons: Using a common degree-day definition increases the variation from one year to the next. As the changes actually are very slow, using a moving average could be defendable.

These degree-days should not be used for national studies, as they don’t describe the national heat demand variations.

All in all, different degree-days are needed for different purposes, particularly for national use and for country comparisons.

[3] dd_1=3500 (17 °C), dd_2=4000 (18°C), dd_{Euro}=2000, Q_1=Q_2=Q => $Q_{1,Euro}$=0.57 Q, $Q_{2,Euro}$=0.50 Q

We need

1. local up-to-date area degree-days.
2. a degree-day for national studies. It should be stable over time, that is, it should have the same formula also for past years (recalculating history).
3. a common degree-day version for country comparisons. It should eliminate the impact of sun radiation, but should show all effects of energy efficiency measures, such as insulation.

5 ODYSSEE

5.1 Werner's method

Some assumptions in the paper of prof. Werner:

"It [the degree-day method] 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."

"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."

As can be seen by the statements, the target for prof. Werner is to create a Use No.2 method (see Chapter 4), a united model that would fit whole of Europe. And prof. Werner states quite correctly that harmonisation is not easy of this kind of a model. Prof. Werner's method[4] might well be used to describe the <u>reasons</u> for the differences in energy efficiencies, but not to describe the efficiencies themselves.

Prof. Werner is arriving at using the square root of the degree-day from the point of cost optimisation. To be able to compare energy efficiencies, energy uses must be related to something that equalizes them fairly, for example floor area, tonnes produced, t-km transported. Energy intensity uses money as a unit, because money is the most common equalizer. However, energy efficiency is not a function of cost or even cost-effectiveness due to market failures. To use cost or cost-effectiveness as a measurement of energy efficiency, as is suggested with the new method, is not supported even by the ODYSSEE Project itself.

Given the building characteristics, such as thicker insulations and triple glazing, which are used in the Nordic countries[5], it is quite commonly expected that there is a reasonable large gap between northern and southern Europe in specific energy

[4] The formula is only for insulation thickness, not for windows or air exchange. The thicker the insulations, the less it affects overall heat losses. Energy and construction costs are assumed to be constant in Europe by Werner, but they are far from it. End-user heating costs are high in the Northern countries, for example electricity (one of the main heat sources) is roughly 12-15 c/kWh whereas in Central Europe or Southern Europe gas may be 5-6 c/kWh.

[5] Insulation thicknesses follow building codes, not cost optimisations. Modern building codes should take into account cost optimisations by all means, but houses are centuries old, so their optimisations might have been very different.

consumptions in an equal climate. However, the square root normalization leads to results which suggest that, for example, specific consumptions in UK and Italy would be lower than those in Finland in an equal climate. This does not appear realistic given the major differences in the building characteristics and does not provide a basis for fair country comparisons.

Prof. Werner also mentions that as the insulation is thicker, the effective indoor temperature is lower. This is true and has to be taken into account in the national degree-days, but should not be taken into account in energy efficiency comparisons. But if it were, then we would also have to take into account the heating costs. Because South European homes have less insulation, the heat losses are higher and thus it is also more costly to keep the indoor temperature at 20-22°C which is normal in the northern countries. The benefit of letting the room temperature drop is much higher in the south than in the north which means that with equal cost-benefit the southern indoor temperature would be 2-3 degrees lower. This should actually be considered in the national degree-days in southern Europe.

5.2 ODYSSEE formulation of adjustment to EU average climate

Looking at the power point presentation “Revised methods for space heating comparison” by Lapillonne et al. (2011) presented in the Warsaw ODYSSEE project meeting, the main formula for EU adjustment is

$$\frac{space\ heating\ consumption\ \times EU27\ ref.dd}{ref.dd}$$

This does not convert the space heating consumption to EU average climate, but to have an average that matches the EU27 ref. climate, assuming that the reference degree-day matches the local degree day average. This is quite misleading as most readers assume the space heating is really converted to the EU reference climate as in

$$\frac{space\ heating\ consumption\ \times ref.dd\ \times EU27\ ref.dd}{dd\ \times\ ref.dd}$$

where dd is the local degree day from the same year as the consumption value. This can be simplified to

$$\frac{space\ heating\ consumption\ \times EU27\ ref.dd}{dd}$$

5.3 Useful energy in ODYSSEE

The idea was to make a study of the different methods using useful energy (ODYSSEE suggests using useful energy). The first thing was to look at specific consumption of useful energy for space heating with climatic corrections, see fig. 4, for some countries.

Fig. 4 shows the development of specific consumption of useful energy for space heating with climatic corrections. Whereas France has a seemingly steady declining development, Finland has a more level and partly growing curve, and Belgium an erratic curve. All curves should, of course, be quite linear or only slowly changing. Some of the problems may arise from the division of delivered heat between heating and hot water. The algorithms are usually not that sophisticated. Another problem lies with how well electricity is split between household electricity and heating. With the introduction of electric bathroom floor heating and air-source heat pumps etc., more and more electricity is used for heating. This may not be taken into account fully in all the statistics.

Also, the used data is specific consumption of useful energy for space heating, where the unit is a dwelling. Here we should also look at the dwelling statistics, Belgium's high modulations might well stem from the dwelling statistics. Another point is also the ratio of single family houses to multifamily houses and apartment flats, as these have different specific consumptions. And the third point is how one arrives at the useful energy: have the statistics been updated to the introduction of condensing gas boilers and what average efficiencies are used (depends on the wanted temperature, which for space heating is different than for hot water heating).

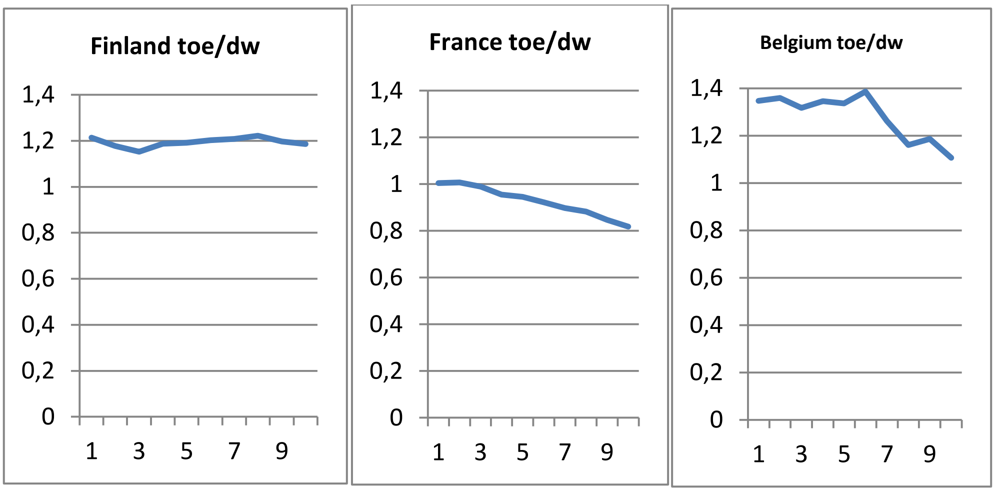

Fig.4. Specific consumption in useful energy for space heating with climatic corrections (ODYSSEE).

It is also possible to look at useful energy use and see how the degree-days compare to the reference degree-days and see how the specific consumption per dwelling and its climate corrected counterpart match, see fig. 5.

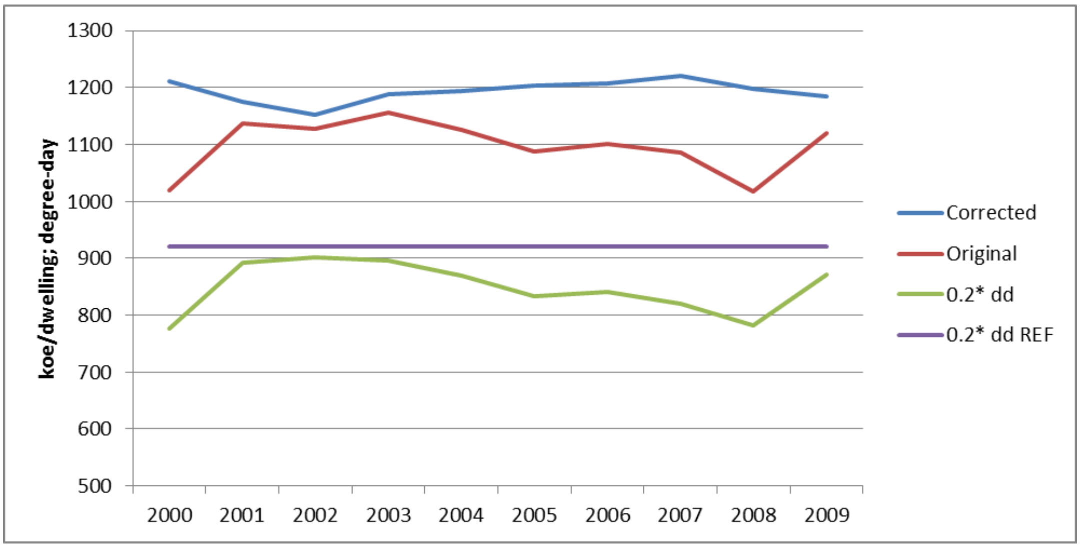

Fig. 5. Finland/Specific consumption of useful energy for space heating with and without climatic corrections. (Degree-days and reference degree-days are multiplied with 0.2 to get the scale suitable for the chart.)

The climatic correction is not flawless, but does improve the stability of the specific consumption curve. Using the square root method, we get fig. 6.

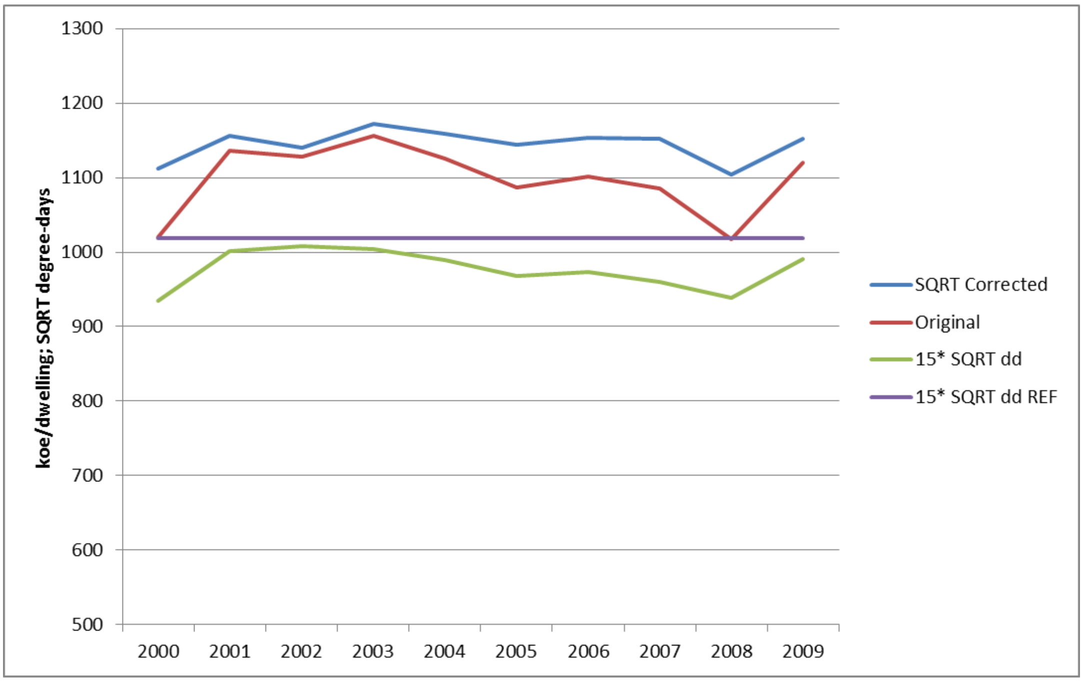

Fig. 6. Finland/Specific consumption in useful energy for space heating with and without climatic corrections using the square root of degree-days for the corrections. (Degree-days and reference degree-days are multiplied with 15 to get the scale suitable for the chart.)

As can be seen, the Werner method does not show any stability improvements in the curve for normalized specific consumption but quite the contrary. This is quite logical, as the consumption is linearly dependent on the degree-days. The challenge is to get the formula for the degree days right, which is not an easy task. Especially the usage of start and stop days for the heating period might be a place for improvement, as well as the choice of the effective indoor temperature.

The same comparison is made for Denmark, see fig. 7 and 8. As Denmark uses a varying reference degree-day[6], we also show what the results would be with a constant reference degree-day. For Denmark the use of square root in normalization shows an improvement in the curve of specific consumption. A similar study should be done for all the countries.

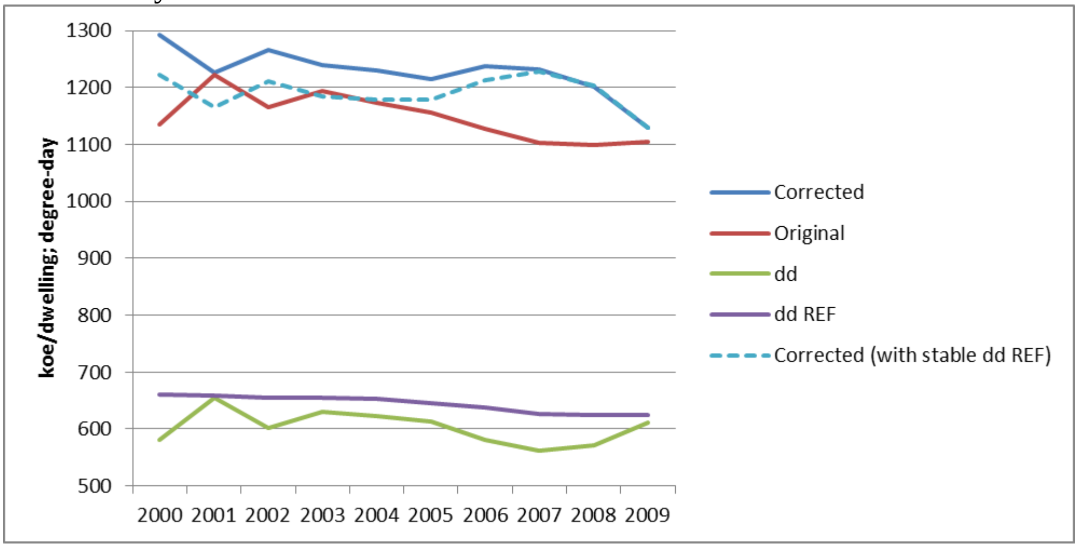

Fig 7. Denmark/Specific consumption in useful energy for space heating with and without climatic corrections. (Degree-days and reference degree-days are multiplied with 0.2.) The alternative climatic correction with constant degree-day uses year 2009 reference dd.

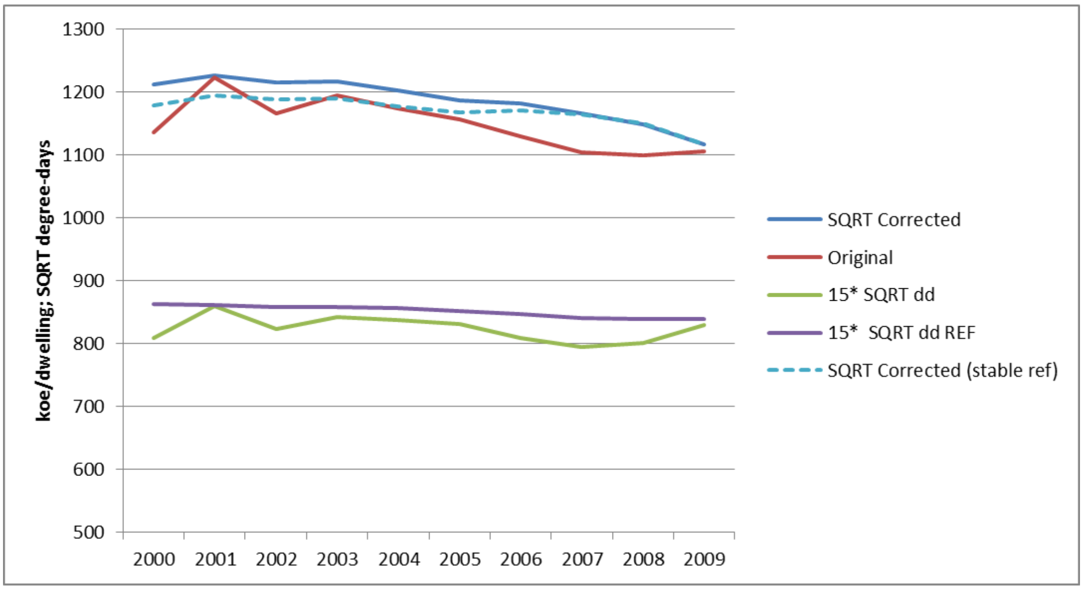

Fig 8. Denmark/ Specific consumption in useful energy for space heating with climatic corrections and without using the square root of degree-days for the corrections. The alternative climatic correction with constant degree-day uses year 2009 reference dd. (Square roots of degree-days and reference degree-days are multiplied with 15).

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[6] Degree-days calculation rules in ODYSSEE are not the same in different countries at the moment, which is as it should be, but this makes country comparisons more difficult, as use no.3 degree-days are missing. The national reference degree-days have been constructed following varying philosophies: Denmark, the Netherland and Spain use varying reference degree-days in 2000-2009, while Romania, Hungary and Cyprus have fluttering references and Sweden has one reference degree change.

Looking at a country comparison, we climate correct all consumption values to an estimated EU reference degree-day of 2600, see fig. 9. The alternative Werner method is shown in fig.10.

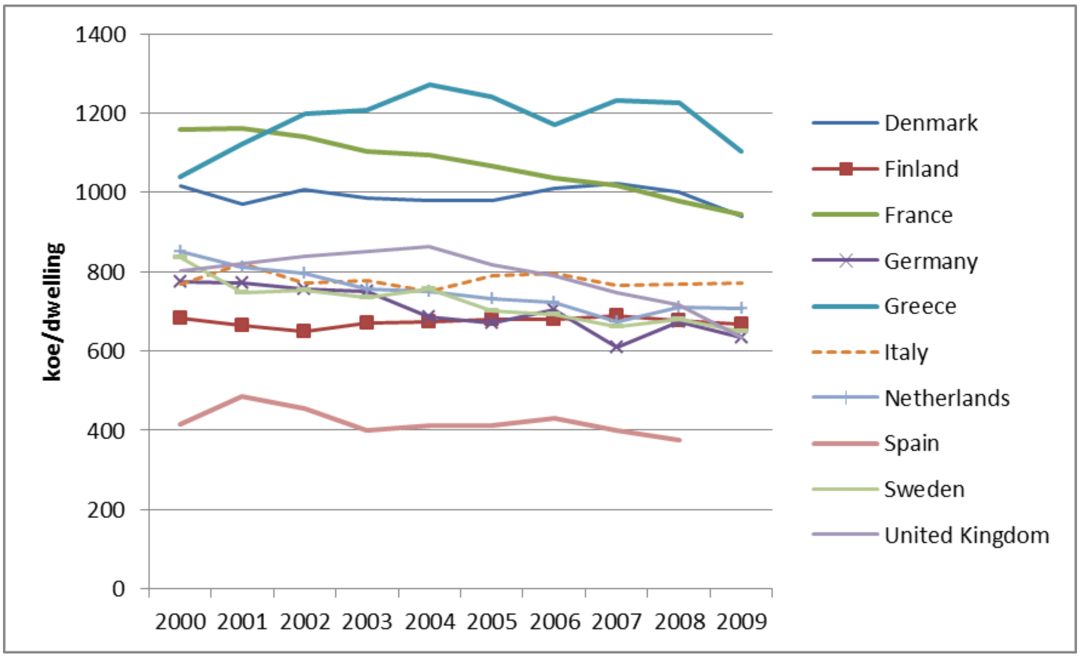

Fig. 9. Specific consumption in useful energy for space heating with climatic corrections to estimated EU average (2600 degree-days).

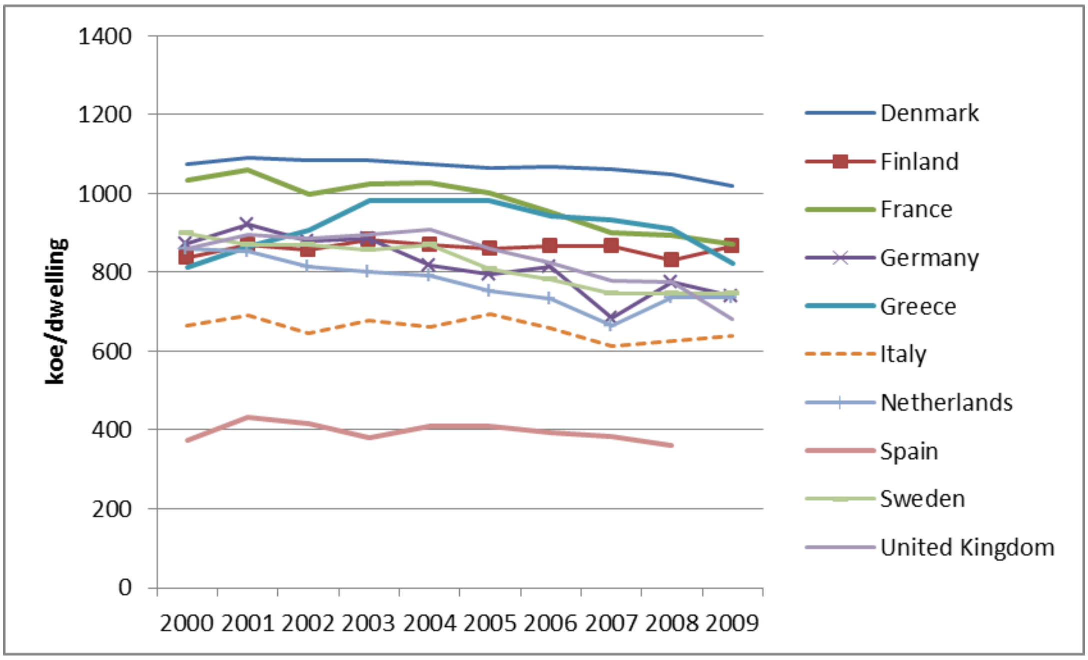

Fig. 10. Specific consumption in useful energy for space heating with climatic corrections to estimated EU average (square root of 2600 degree-days) using the Werner method.

When comparing Fig. 9 and Fig 10 we see that specific consumptions drop a lot in Italy, Greece and France but they grow most in Finland. The Werner method (Fig. 10) improves the result for countries that have low degree-days and impairs the result for those having high degree-days. The only point of using a climatic correction to an EU average level is to actually assess what the heat consumptions would be if the temperature would be the same all over Europe. An alternative illustration of the evaluation objective would be to imagine all the houses in the middle of the EU. Which ones would have higher energy consumption and which ones lower, all things equal?

6 Summary and conclusions

It has been suggested in the ODYSSEE project of the EU's Intelligent Energy for Europe Programme (IEE) to use a new method to correct for climatic differences. Nowadays degree-days are used linearly, and the new proposition is to use the square root of degree-days (so-called Werner method) in climatic corrections. The objective of this analysis was to investigate which is more correct and fair in country comparisons.

The suggested Werner's method for climatic correction has a major fundamental drawback: it is based the costs. Cost (and cost-effectiveness) is not suggested to be a metrix of energy efficiency in the ODYSSEE Project itself.

If we have a metrix that is applicable for energy efficiency comparisons and estimations (i.e. specific energy consumption), it makes no sense to eliminate its energy efficiency linkage. Therefore, we should not try to eliminate the thickness of the insulation from degree-days.

Heating energy consumption is proportional to the degree-days, not to the square root of degree-day. A method based on the square root of degree-day is therefore physically incorrect if it is used in climate correction of heating energy. Also as seen by the results, it does not improve the smoothness of the climatic corrections for individual countries.

The square root method gives results which suggest that the buildings in southern Europe are more energy efficient than those in the northern Europe at identical climate conditions which is not conceivable given the building characteristics.

In general, the usage of degree-days depends on what is the objective of the analysis. We need different degree-days for national analyses and for country comparisons. In national analyses, there are good reasons why countries use their own degree-day formulations. However, in country comparisons, a new common degree-day would be useful.