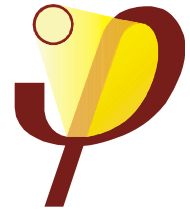




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PEP Project Information

Climate Data for the Determination of Passive House Heat Loads in Northwest Europe

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1 Determination of Heat Load

The maximum heat load is the crucial parameter for the function of a Passive House. If the heat load can be covered by heating the supply air, a separate heat distribution system will not be necessary any more, resulting in lower investment cost and rendering extremely high energy efficiency affordable.

The present paper is divided into three sections: First, a procedure is developed which allows to determine heat load design data for the Passive House Planning Package [PHPP 2004] from hourly data of typical years. Then, results for the PEP partner countries which have been obtained using this procedure, are summarized. Finally, a parametric study gives first indications about Passive House requirements under the different climatic conditions.

Unlike in conventional buildings, in Passive Houses the heat load does not necessarily occur during the period when the ambient temperature reaches a minimum. Periods with the lowest temperatures in a specific location usually occur when the sky is clear, because the ground radiates more heat into the sky and thus becomes colder. Generally (except for locations north of the polar circle) this means that the coldest periods are sunny. A south-oriented Passive House with little shading can therefore use relatively high solar gains to cover part of its heat losses during the coldest periods. In many cases, the maximum heat load will therefore occur during less cold, but overcast periods.

Given this situation, the PHPP considers two separate design periods for the calculation of the heat load. The heat load is calculated independently for both periods, the maximum of the two results is then used as the design heat load. The procedure takes into account internal and solar gains as well as the thermal inertia of the building.

The heat load calculation in the PHPP contains several safety margins:

- The internal heat gains are reduced from 2.1 W/m² to 1.6 W/m². This increases the available heating power by 0.5 W/m².
- Infiltration losses are increased to 250% of the average annual value to account for the more powerful stack effect and possible strong winds during the heat load period. In the example considered below (at $n_{50} = 0.3$ /h) this increases the heat load by 0.6 W/m². In buildings with worse airtightness the effect is accordingly stronger.
- The solar radiation design data are rounded down to full 5 W/m² steps, i.e. by 2.5 W/m² on average. In the example building this increases the heat load by 0.1 W/m².



- In unusually cold periods the ground temperature under the building is not noticeably reduced; the heat losses through the ground remain unchanged. This effect is most important for low-rise buildings.

Altogether, the PHPP heat load design algorithm contains safety margins of approximately 1.5 W/m².

In order to determine the design data – i.e. ambient temperature and solar radiation in different directions as daily averages –, it is necessary to perform a number of dynamic thermal simulations based on hourly data. Details about the procedure can be found in [Feist 2005] and [Bisanz 1998]. For the work within the PEP project, the procedure was checked, updated and supplemented in order to facilitate the practical handling with a larger number of different climate data sets. Detailed tests revealed that the properties of the building prototype which is used for the determination of the heat load design data do not influence the results significantly: Worse insulation, larger window areas or similar changes do not affect the design data determined, as long as the heat load of the building is on the order of 10 W/m².

2 Determining Design Heat Load Data from Typical Climate Data

The choice of the hourly climate data sets which are used to determine the heat load design data is obviously decisive for the results. Due to the strong variations of the weather between different years it is not sufficient to use measured data from an arbitrary winter. Ideally, climate data from a ‘design winter’ would be used, the respective period being severe enough to guarantee that the design data derived from it will result in a building that can be kept at the desired temperatures during e.g. 99.5% of the time (see also section 2.2 below).

Unfortunately, this goal is far too ambitious. In most cases, only isolated annual data sets were available, climate data which would directly be suitable for design purposes can generally not be traced. Therefore, it was necessary to develop a procedure for the determination of heat load design data using a typical winter.

2.1 German Test Reference Years 2004

In 2004, the German weather service (‘Deutscher Wetterdienst’, DWD) released new test reference years (TRY2004). These contain measured data sets of the parameters required here, in particular of dry bulb temperature and the corresponding direct and diffuse solar radiation. The periods which make up the TRYs have been chosen from the years 1961 to 1995 in such a way that the averages of the climatic elements correspond as good as possible to the respective averages of the meteorological seasons (winter: December to February, spring:



March to May, etc.). At the same time, the general European weather situation should be as typical as possible. In other words: The TRYs are typical years.

The 2004 TRYs were especially useful because there are not only typical, but also extreme data sets available. The extremely cold data set contains data from the winter 1984/85, which throughout Germany exhibited unusually low temperatures occurring once in about every 10 years (designated TRY2004_EXT hereafter).

Figure 1 illustrates the differences between typical and extreme winters using the example of the TRY region 12 (Mannheim).

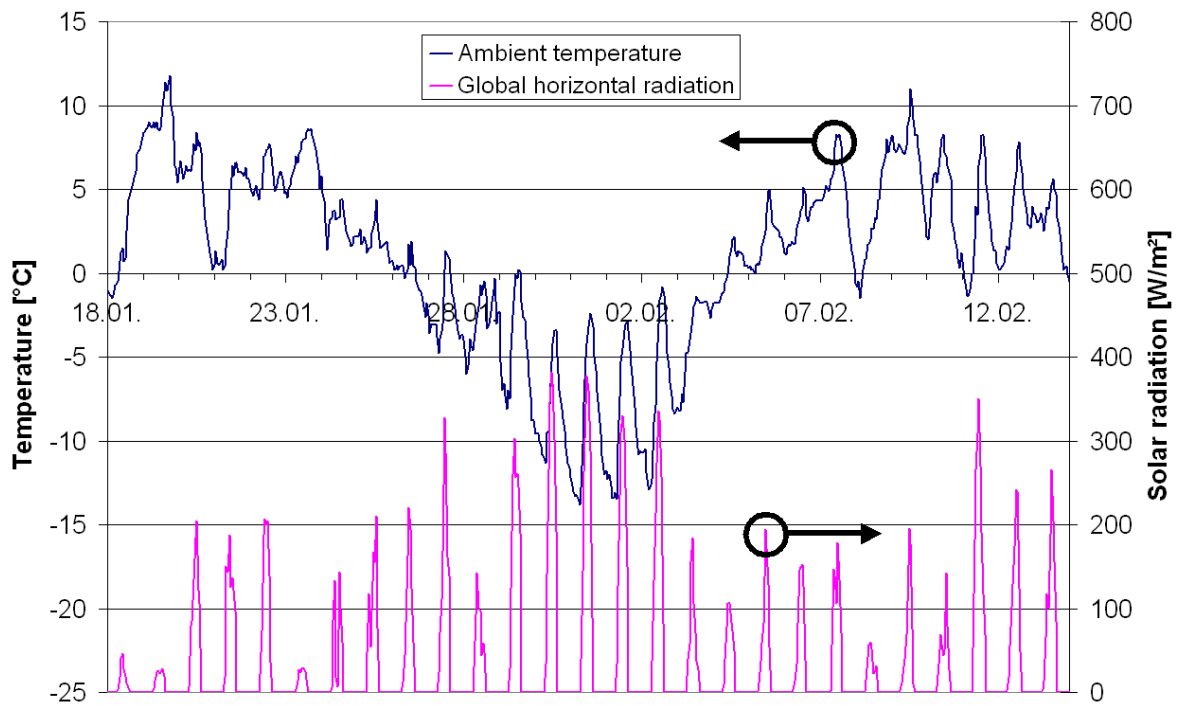
2.2 Significance of the Extreme Winter Data

Should the heating system of a building be designed to cope with the worst weather conditions that may ever be encountered during the lifetime of the building? It is common practice not to design systems to the worst possible case, as long as in case of missing power there will not be severe consequences such as injuries. Domestic hot water systems, for example, are generally designed using utilisation factors which take account of the fact that not all users draw hot water at the same time, thus allowing for smaller systems. The design temperatures in the German DIN EN 12831 follow a similar procedure: They do not relate to the coldest winter of the last 100 years, but to the lowest two-day average that has been achieved at least 10 times during 20 years, i.e. a weather situation which on average occurs once every two years.

Therefore, a heating system will not be required to exactly keep up the setpoint temperature under the TRY2004_EXT conditions, which in the past occurred once every 10 years. The acceptable deviation can be derived from an ASHRAE 55 draft [ASHRAE 2003]. It defines different comfort classes depending on the temperature variation. The highest Comfort Class A is equivalent to $|\Delta PMV| \leq 0.22$, which translates to a temperature deviation of ± 0.8 K. At this deviation, the predicted percentage of dissatisfied (PPD) rises from 5% to 6%.



Coldest period of TRY2004



Coldest period of TRY2004_EXT

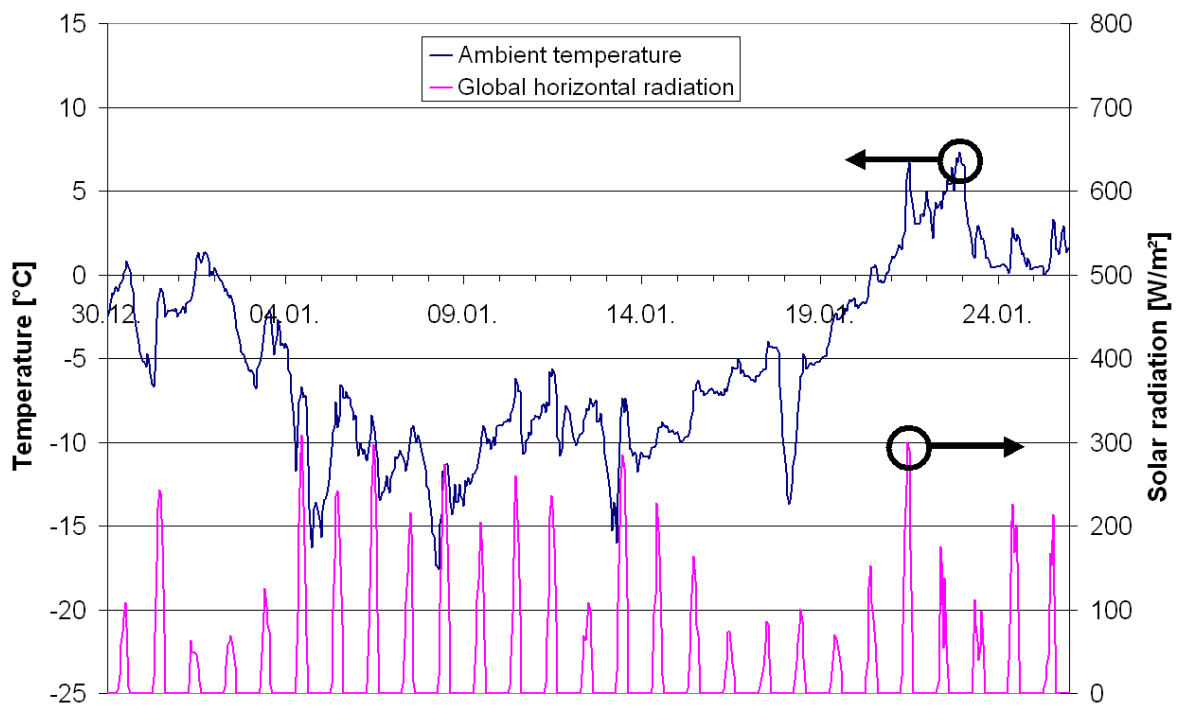


Figure 1: Cold periods in the German TRY 12 from TRY2004 and TRY2004_EXT



2.3 Proposal for the Determination of Design Data

After several tests for different climatic zones, the following procedure has been identified to result in appropriate design data if only weather data for a typical year at a specific location are available:

- The design data are determined using the typical year.
- The design temperatures are reduced by 1 K.
- To take account of the fact that in a cold, sunny period the radiation from the typical year will not necessarily be available in full, all radiation values are reduced as follows: The radiation Q_N on the north façade is considered to be unaffected, diffuse radiation. The radiation on the other façades is calculated according to $Q_i' = Q_N + (Q_i - Q_N)/2$.
- The radiation data are rounded down to full 5 W/m².

2.4 Tests of the Proposed Algorithm

The proposed procedure has been tested for different German climates. In the following, two extreme examples are reported.

2.4.1 TRY 1 (Coastal Region at North Sea)

Influenced by the nearby sea, this region has relatively mild winters, but generally not very much sun.

If the corrected data derived from the typical year are used for the climatic conditions of the respective TRY2004_EXT, the indoor temperatures stay in the range of ASHRAE Comfort Class A except for 5 hours of this extremely cold year.



Average air temperature in the building during the design period (TRY 1, extremely cold winter)



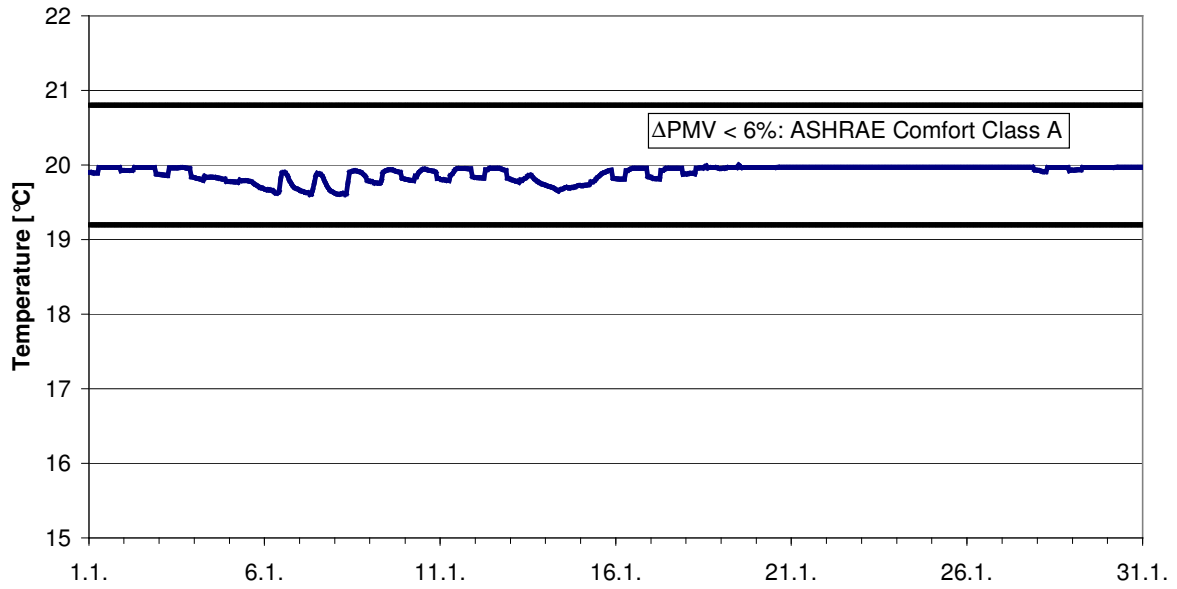
2.4.2 TRY 11 (Highland Mountain Tops)

Concerning the surface area, and all the more the number of buildings, this region is relatively small. The climate is considerably colder than in the rest of Germany, which makes the climate particularly interesting both in the context of the PEP project and as being opposed to the coastal region described above.

Again, the proposed algorithm for deriving and correcting the heat load design data proves to be appropriate.



**Average air temperature in the building during the design period
(TRY 11, extremely cold winter)**





3 PHPP Climate Data for the PEP Partner Countries

All PEP partners were requested to provide suitable data for the determination of heat load data for their countries. The data that were transferred to the Passive House Institute have been processed; in addition, for those countries where partners could not provide data, typical years from [ASHRAE 2001] were used in order to derive at least one complete climate data set per country.

The following table shows the results. After completion, the partners received these data; the data will also be integrated in the forthcoming edition of the PHPP. Temperatures are given in °C, monthly solar radiation sums in kWh/(m² month).

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Heat Load | °C or W/m ² |
|------------------------|------|------|------|-------|-------|-------|-------|-------|-------|------|------|------|-----------|------------------------|
| | | | | | | | | | | | | | Period 1 | Period 2 |
| D - Example | | | | | | | | | | | | | | |
| Temp | -1.7 | -0.5 | 3.3 | 7.5 | 12 | 15.5 | 17.3 | 16.6 | 13.5 | 8.2 | 3.2 | -0.4 | -6.0 | -2.0 |
| South | 41.4 | 61.5 | 70.8 | 71.8 | 72.2 | 63.4 | 73.5 | 82.3 | 79.6 | 73.0 | 41.9 | 34.2 | 50 | 10 |
| East | 16.0 | 28.0 | 44.9 | 64.2 | 81.7 | 74.7 | 86.8 | 78.4 | 53.0 | 35.9 | 16.3 | 13.2 | 15 | 5 |
| North | 10.4 | 16.1 | 26.1 | 35.1 | 44.7 | 47.8 | 48.7 | 38.8 | 26.6 | 17.6 | 10.3 | 7.9 | 10 | 5 |
| West | 18.0 | 32.0 | 48.2 | 63.8 | 76.6 | 74.3 | 82.2 | 72.7 | 55.4 | 37.5 | 18.7 | 13.8 | 15 | 5 |
| Global | 29.7 | 50.6 | 83.8 | 118.9 | 159.6 | 155.7 | 174.3 | 149.1 | 101.1 | 64.8 | 31.2 | 21.6 | 20 | 5 |
| A - Wien IWEK | | | | | | | | | | | | | | |
| Temp | -0.1 | -0.5 | 5.3 | 10.3 | 15.2 | 16.8 | 20.2 | 20 | 15 | 10.7 | 4.6 | -0.2 | -11.1 | -4.7 |
| South | 29.4 | 56.8 | 80.2 | 85.5 | 93.3 | 88.1 | 97.5 | 102.8 | 79.8 | 60.3 | 31.2 | 22.2 | 75 | 10 |
| East | 16.2 | 28.2 | 47.6 | 66.6 | 86.0 | 89.1 | 95.3 | 84.9 | 55.5 | 36.2 | 17.1 | 11.5 | 35 | 10 |
| North | 11.6 | 14.9 | 28.2 | 39.2 | 51.8 | 56.4 | 55.2 | 43.7 | 34.0 | 21.4 | 11.8 | 8.6 | 20 | 5 |
| West | 15.0 | 26.0 | 48.1 | 64.7 | 79.2 | 86.5 | 86.2 | 78.8 | 51.9 | 32.4 | 15.6 | 11.4 | 30 | 10 |
| Global | 25.9 | 44.7 | 83.3 | 120.3 | 155.7 | 161.5 | 172.8 | 154.8 | 97.2 | 59.4 | 27.8 | 19.0 | 45 | 10 |
| DK - København | | | | | | | | | | | | | | |
| Temp | -0.5 | -0.9 | 1.7 | 5.4 | 11.3 | 14.5 | 16.4 | 16.2 | 12.1 | 9.1 | 4.7 | 1.5 | -10.8 | -6.5 |
| South | 35.3 | 50.9 | 73.4 | 90.7 | 108.0 | 97.7 | 97.7 | 101.7 | 79.6 | 58.5 | 36.2 | 22.8 | 55 | 10 |
| East | 12.1 | 21.1 | 46.4 | 69.4 | 105.6 | 95.2 | 89.8 | 76.5 | 52.6 | 26.3 | 13.4 | 7.2 | 15 | 5 |
| North | 5.9 | 11.4 | 21.5 | 35.6 | 51.1 | 58.9 | 56.2 | 40.2 | 25.6 | 13.7 | 6.7 | 4.2 | 5 | 5 |
| West | 12.2 | 23.4 | 40.2 | 75.7 | 89.8 | 99.1 | 99.5 | 79.2 | 54.7 | 31.1 | 12.6 | 7.8 | 15 | 5 |
| Global | 15.5 | 32.0 | 65.0 | 114.0 | 163.4 | 164.9 | 160.0 | 134.0 | 81.7 | 42.6 | 18.9 | 10.3 | 15 | 5 |
| IRL - Birr | | | | | | | | | | | | | | |
| Temp | 4.0 | 3.3 | 7.8 | 7.7 | 11.6 | 11.7 | 15.7 | 16.0 | 13.3 | 9.4 | 6.7 | 6.8 | -1.4 | 0.9 |
| South | 48.2 | 43.3 | 62.4 | 70.1 | 90.5 | 78.4 | 72.2 | 84.5 | 81.8 | 51.9 | 41.4 | 19.1 | 45 | 10 |
| East | 18.1 | 23.9 | 41.9 | 54.6 | 75.4 | 75.0 | 67.0 | 63.9 | 51.4 | 27.0 | 13.5 | 7.8 | 25 | 5 |
| North | 7.5 | 13.1 | 22.2 | 33.3 | 54.5 | 57.6 | 50.9 | 43.8 | 31.5 | 17.0 | 9.1 | 5.6 | 15 | 5 |
| West | 16.2 | 22.6 | 41.7 | 61.4 | 93.2 | 83.6 | 70.7 | 70.4 | 61.2 | 32.3 | 20.2 | 8.5 | 25 | 5 |
| Global | 22.5 | 34.0 | 63.5 | 92.5 | 144.6 | 134.0 | 119.0 | 118.0 | 92.7 | 46.0 | 24.9 | 12.7 | 35 | 10 |
| GB - Manchester | | | | | | | | | | | | | | |
| Temp | 4.9 | 4.3 | 6.6 | 7.7 | 11.9 | 13.7 | 16.1 | 14.8 | 12.8 | 10.2 | 6.3 | 6 | -0.8 | 0.5 |
| South | 36.7 | 47.5 | 67.5 | 91.4 | 93.9 | 84.6 | 87.7 | 87.0 | 64.7 | 51.2 | 31.9 | 19.6 | 25 | 10 |
| East | 16.3 | 29.1 | 47.1 | 71.7 | 88.1 | 75.5 | 74.2 | 69.9 | 46.4 | 28.4 | 13.5 | 8.1 | 5 | 5 |
| North | 7.7 | 13.2 | 26.0 | 38.7 | 50.7 | 57.4 | 52.4 | 43.4 | 30.5 | 17.9 | 8.5 | 5.2 | 5 | 5 |
| West | 12.6 | 21.1 | 43.4 | 72.5 | 88.3 | 92.5 | 85.0 | 74.4 | 47.6 | 30.0 | 14.9 | 8.5 | 10 | 5 |
| Global | 19.9 | 35.1 | 70.9 | 117.9 | 149.0 | 144.8 | 144.2 | 124.9 | 77.0 | 46.7 | 21.0 | 11.8 | 10 | 10 |



| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Heat Load | °C or W/m ² |
|-----------------------------|------|------|------|-------|-------|-------|-------|-------|------|------|------|------|-----------|------------------------|
| | | | | | | | | | | | | | Period 1 | Period 2 |
| NL - Amsterdam IWE C | | | | | | | | | | | | | | |
| Temp | 4.2 | 3.3 | 5.3 | 8.2 | 12.7 | 14.7 | 16.9 | 17.1 | 13.9 | 10.8 | 6.3 | 4.4 | -2.9 | -1.9 |
| South | 30.5 | 51.7 | 79.6 | 75.7 | 94.1 | 86.5 | 91.9 | 87.1 | 70.3 | 50.0 | 33.5 | 21.3 | 20 | 10 |
| East | 13.1 | 23.8 | 43.2 | 54.6 | 83.0 | 79.0 | 74.9 | 65.1 | 45.7 | 27.6 | 14.9 | 8.9 | 10 | 5 |
| North | 8.1 | 13.5 | 25.0 | 36.7 | 53.1 | 52.7 | 50.0 | 44.7 | 29.8 | 19.8 | 10.1 | 6.3 | 5 | 5 |
| West | 12.7 | 23.8 | 47.9 | 60.7 | 82.2 | 82.4 | 86.6 | 72.4 | 47.3 | 29.5 | 15.5 | 9.4 | 5 | 5 |
| Global | 19.8 | 38.1 | 76.8 | 102.9 | 149.2 | 147.8 | 153.0 | 126.0 | 81.6 | 48.1 | 24.7 | 14.4 | 10 | 10 |
| B - Brussels IWE C | | | | | | | | | | | | | | |
| Temp | 3.1 | 2.9 | 6.4 | 8.6 | 12.9 | 15.1 | 18.4 | 17.4 | 14 | 10.9 | 6.4 | 4.9 | -4.6 | -1.5 |
| South | 25.5 | 40.0 | 52.0 | 68.6 | 82.8 | 77.0 | 86.7 | 82.7 | 64.8 | 53.3 | 35.1 | 16.6 | 90 | 5 |
| East | 12.1 | 18.8 | 32.3 | 50.8 | 69.1 | 71.5 | 75.6 | 64.4 | 42.4 | 28.0 | 14.8 | 8.2 | 25 | 5 |
| North | 9.1 | 14.1 | 25.3 | 38.0 | 53.1 | 57.1 | 53.9 | 46.8 | 31.0 | 21.5 | 10.9 | 6.8 | 15 | 5 |
| West | 13.3 | 23.8 | 37.6 | 59.2 | 84.1 | 77.4 | 87.2 | 76.5 | 48.6 | 35.4 | 18.7 | 10.1 | 40 | 5 |
| Global | 20.4 | 34.7 | 59.9 | 95.7 | 134.4 | 130.3 | 145.8 | 125.1 | 78.4 | 52.3 | 26.8 | 14.1 | 50 | 10 |
| N - Bergen | | | | | | | | | | | | | | |
| Temp | 1 | 0.5 | 2.6 | 4.6 | 9.4 | 11.7 | 13.6 | 13.2 | 10.2 | 7.3 | 3.8 | 1.1 | -6.2 | -5.7 |
| South | 12.0 | 38.1 | 59.9 | 82.0 | 94.3 | 88.2 | 87.2 | 76.7 | 51.9 | 43.7 | 14.7 | 6.4 | 25 | 10 |
| East | 6.1 | 15.9 | 34.1 | 57.2 | 74.8 | 78.1 | 71.4 | 57.1 | 31.4 | 18.1 | 5.9 | 3.0 | 10 | 5 |
| North | 3.6 | 7.2 | 17.4 | 32.9 | 42.6 | 47.2 | 51.5 | 34.9 | 20.2 | 10.3 | 4.1 | 2.1 | 5 | 5 |
| West | 4.1 | 11.8 | 32.4 | 68.4 | 80.7 | 84.4 | 88.9 | 68.9 | 33.9 | 20.4 | 5.4 | 2.3 | 5 | 5 |
| Global | 7.6 | 19.4 | 50.3 | 98.2 | 133.0 | 138.9 | 133.8 | 100.7 | 52.8 | 28.4 | 9.4 | 4.1 | 10 | 5 |
| N - Oslo | | | | | | | | | | | | | | |
| Temp | -3.7 | -4.4 | -0.5 | 4.7 | 11.7 | 16 | 17.5 | 16.9 | 11.2 | 6.4 | 0.5 | -2.5 | -14.5 | -8.6 |
| South | 23.2 | 48.5 | 81.6 | 101.0 | 102.6 | 111.7 | 107.2 | 106.5 | 80.9 | 51.9 | 31.5 | 20.5 | 30 | 10 |
| East | 7.2 | 18.6 | 39.9 | 79.0 | 86.9 | 110.6 | 101.0 | 74.4 | 45.3 | 22.7 | 10.8 | 5.3 | 10 | 5 |
| North | 3.8 | 10.2 | 19.7 | 33.2 | 49.1 | 61.3 | 54.5 | 36.6 | 23.1 | 10.5 | 5.0 | 2.3 | 5 | 5 |
| West | 7.9 | 21.4 | 54.1 | 63.2 | 89.1 | 105.0 | 95.0 | 85.1 | 56.9 | 23.7 | 9.2 | 4.3 | 15 | 5 |
| Global | 9.4 | 28.9 | 66.2 | 111.4 | 147.6 | 180.2 | 163.9 | 130.4 | 77.0 | 33.8 | 13.9 | 6.0 | 15 | 5 |
| FIN - Helsinki IWE C | | | | | | | | | | | | | | |
| Temp | -3.9 | -5.1 | -1 | 3.6 | 9.9 | 13.6 | 16.7 | 15.7 | 9.9 | 5.9 | -1.2 | -3 | -17.3 | -14.6 |
| South | 14.0 | 48.2 | 67.2 | 90.2 | 119.9 | 112.4 | 115.8 | 96.9 | 64.6 | 38.5 | 10.5 | 3.6 | 45 | 5 |
| East | 5.7 | 20.4 | 40.4 | 70.2 | 101.2 | 101.9 | 93.0 | 70.7 | 42.5 | 22.8 | 6.3 | 2.4 | 20 | 5 |
| North | 3.7 | 8.6 | 20.7 | 38.8 | 53.4 | 60.5 | 56.8 | 45.1 | 28.8 | 14.9 | 4.7 | 2.0 | 10 | 5 |
| West | 4.8 | 16.6 | 32.9 | 61.8 | 87.8 | 90.2 | 90.2 | 67.7 | 38.7 | 20.7 | 5.6 | 2.2 | 15 | 5 |
| Global | 7.8 | 25.5 | 57.9 | 107.3 | 164.6 | 172.3 | 168.7 | 124.5 | 70.4 | 34.8 | 9.4 | 3.7 | 20 | 5 |



4 A Parametric Study for Northwest Europe

With at least one data set for the calculation of annual space heat demand and heat load within the PHPP being available for each PEP partner country, it became possible to address the question what it means to build Passive Houses in Northwest European climates outside Germany.

The basic idea of the Passive House concept – to improve energy efficiency just so much that a separate heat distribution system is not necessary any more and thereby reduce investment costs – holds for all climates. This limit is roughly equivalent to a maximum space heat load of 10 W per square meter living area, independent of the climate.

The design data were first used to determine the required insulation levels of an example building for a heat load of 10 W/m². Afterwards, for each climate, the corresponding annual space heat demand and the effects of changing the area of the south facing windows on heat load and space heat demand were investigated. For all climates, an identical building geometry and identical internal gains were used.

4.1 Example Building Geometry

The study was performed using the example contained in the PHPP. This building is basically an end-of-terrace dwelling unit in the first Passive House, which was built in Darmstadt-Kranichstein, Germany, in 1991. It has a relatively good ratio of exterior area to enclosed volume (0.59 m⁻¹), is facing due south and has large south facing windows (30.4 m² gross window area, 19.9 m² glazed area in an overall 74 m² façade). Like the original house in Darmstadt, the example is assumed to be very airtight ($n_{50} = 0.22 \text{ h}^{-1}$) and to have a highly efficient heat recovery and a subsoil heat exchanger ($\eta_{\text{total}} = 0.87$).



Figure 2: The first Passive House in Darmstadt-Kranichstein which was used as an example in this study

4.2 Technical Limits

In moving the Passive House standard further north, the thermal quality of the thermal envelope will need to be improved. In this process, technical limits may be encountered. This section tries to identify a range of thermal properties which can be covered with readily available components. For all components, further improvements are technically possible.

4.2.1 Window Quality

In Germany, Passive House windows typically have overall U-values of $0.85 \text{ W}/(\text{m}^2\text{K})$ including the thermal bridge resulting from the installation in the wall. This is achieved with highly insulating window frames and triple glazing with low-e-coating and argon gas filling. The glazing U-value would then be $0.7 \text{ W}/(\text{m}^2\text{K})$. In northern climates, it may be necessary to use even better windows. Triple glazing with Krypton filling can achieve U-values down to 0.51. All current Passive House frames have about the same insulation level, which is quite close to the limits imposed by the certificate „component suitable for Passive Houses“. The thermal quality of window frames can still be improved, though. First estimates showed that a standard size (1.23 m x 1.48 m) window with an improved frame, very good triple glazing and good installation in the wall ($\Psi_{\text{inst}} \approx 0$) would have a U-value of $0.56 \text{ W}/(\text{m}^2\text{K})$. With two standard low-e double glazing layers, each in a good frame and combined to form a



casement window, a U-value on the same order of magnitude is possible. The total solar transmittance g of triple glazings is typically slightly above 50%.

For cold climates, we assume that windows with a total U-value of $0.6 \text{ W}/(\text{m}^2\text{K})$ and a g -value of 0.5 can be made available.

4.2.2 Insulation of opaque building elements

On rare occasions, buildings have been built with up to 60 cm of insulation in the roof. The thermal conductivity of the insulation being $0.035 \text{ W}/(\text{mK})$, this would result in a U-value below $0.06 \text{ W}/(\text{m}^2\text{K})$. For walls, exterior insulation and finish systems (EIFS) with a thickness of 40 cm are registered as standard building products in Germany, resulting in a U-value of ca. $0.085 \text{ W}/(\text{m}^2\text{K})$.

We assume that U-values of $0.08 \text{ W}/(\text{m}^2\text{K})$ for walls and $0.06 \text{ W}/(\text{m}^2\text{K})$ for roofs can be realized.

4.2.3 Heat recovery

It is sometimes considered doubtful whether heat recovery works in cold Northern European climates: Due to the low temperatures, freezing of the heat exchanger might occur frequently, which would result in a reduction of the achievable annual efficiency. It appears that due to low humidity levels in the buildings, this problem is not very significant in practice. It can be overcome by using rotary wheel heat exchangers or by preheating of ambient air with subsoil heat exchangers. More sophisticated control mechanisms can also provide the full sensible efficiency of plate heat exchangers even in cold climates [Schmeisser 2006].

In this study, the heat recovery efficiency of 0.87 is assumed to be achievable throughout the study area.

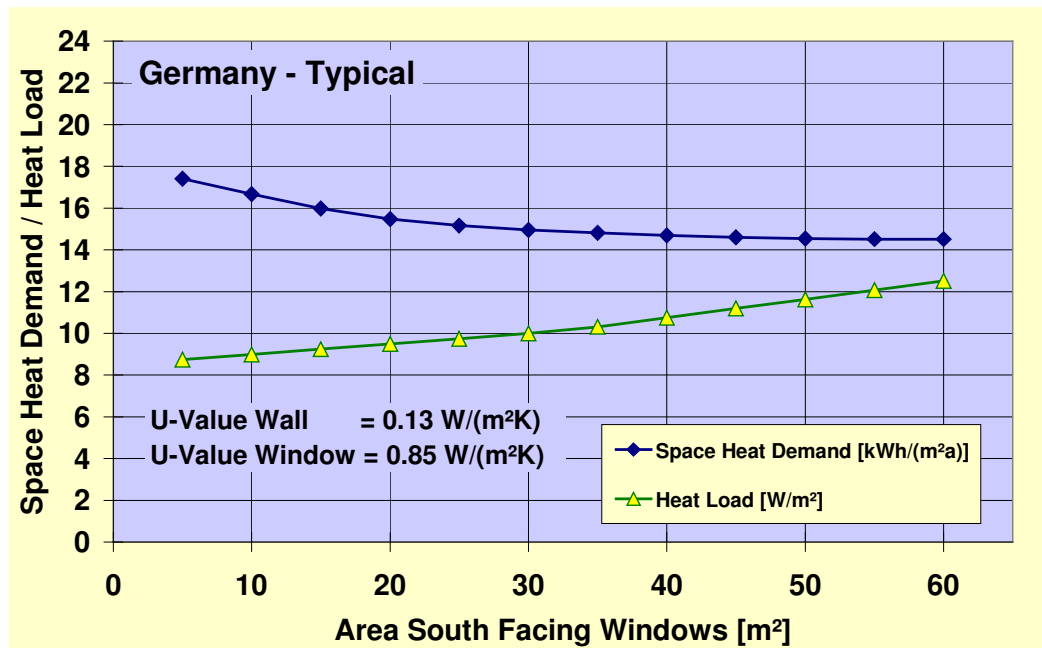
4.3 Results

For each climate zone, we tried to identify a typical solution for a heat load of $10 \text{ W}/\text{m}^2$ (including safety margins). In a first step, this was done by adapting the insulation level of the opaque parts of the shell; if that was not sufficient, the window quality and size were also changed.

In the following diagrams, for reasons of simplicity, the U-values of the floor are always the same as for the walls, whereas the roof U-value is 71 % of this. Total solar transmittance of the glazing is always assumed to be 50%.



4.3.1 Germany



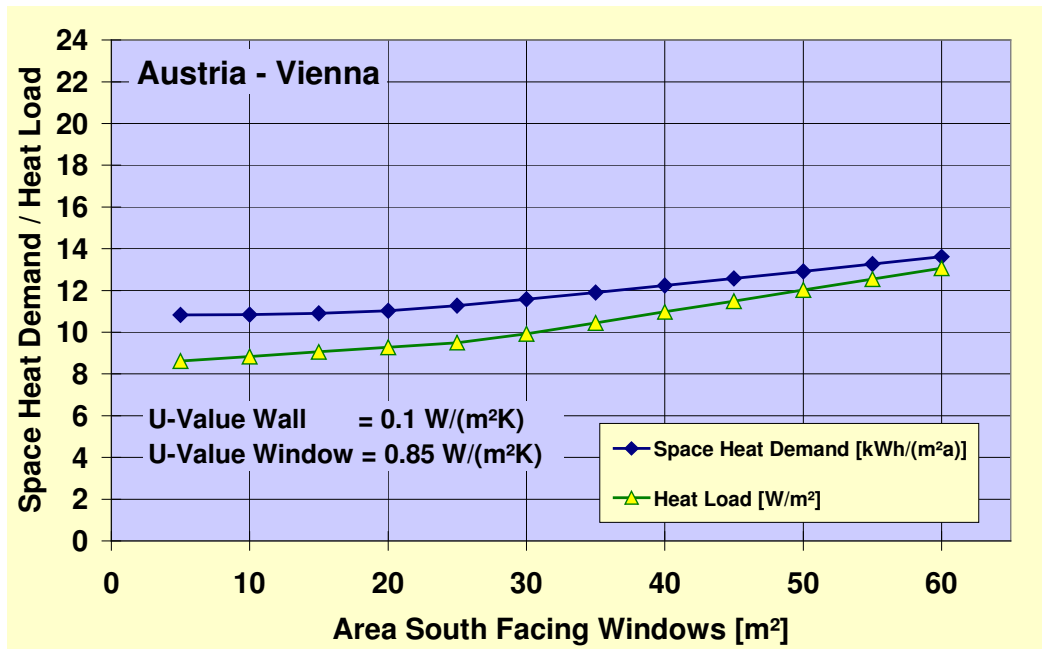
The climate data for Germany are based on an example climate data set from the PHPP. U-values for the walls have to be about 0.13 W/(m²K) in order to reach the 10 W/m² limit. Typical Passive House windows with an overall U-value of 0.85 W/(m²K) must be used.

With increasing window area, the heat load is also increasing, whereas the annual space heat demand is decreasing. In this example, a heat load of 10 W/m² corresponds nearly exactly to a space heat demand of 15 kWh/(m²a).

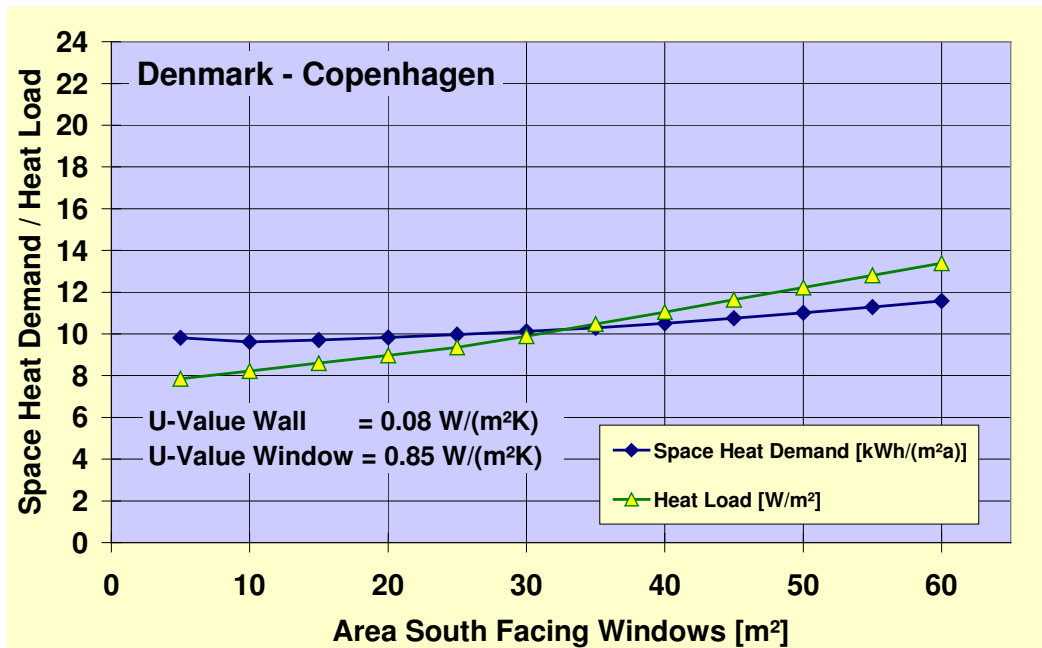
4.3.2 Austria

For Vienna, climate data from [ASHRAE 2001] formed the basis of the calculations. These data contain a relatively short period with very low temperatures down to -17 °C. Design temperatures in Vienna are therefore lower than in Germany, and more insulation is needed to achieve a heat load of 10 W/m². The standard Passive House windows are still sufficient.

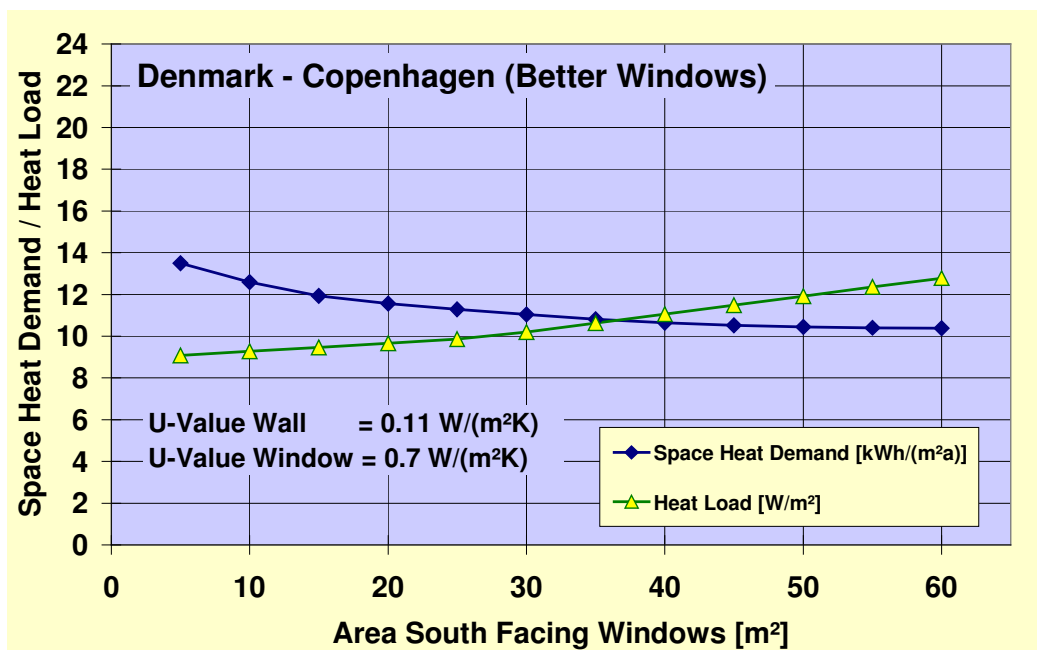
Average solar radiation levels are lower than in the German reference case. Given the window quality used here, larger windows then result in larger space heat demand.



4.3.3 Denmark

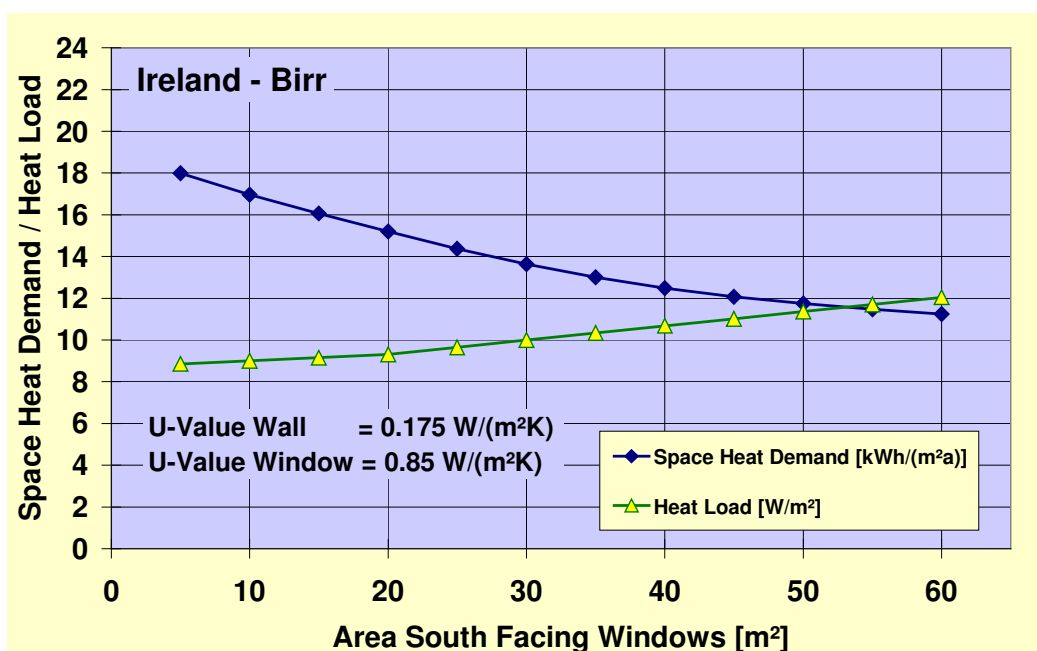


The climate data set for Copenhagen that was used (TRY Copenhagen) contains a cold spell with temperatures below -20 °C. This appears rather exceptional if compared to the typical climate on the German coast of the Baltic Sea with -15 °C. The low temperature during a short period results in relatively low annual space heat requirements at a heat load of 10 W/m². Using the typical window quality, very good insulation of the walls, etc., is required.



In Copenhagen, less solar radiation is available during the heating season than in Germany. Therefore, with the same window quality, larger windows lead to a larger space heat demand. If, on the contrary, windows with $U = 0.7 \text{ W}/(\text{m}^2\text{K})$ instead of $0.85 \text{ W}/(\text{m}^2\text{K})$ are used, increasing the area of the south facing windows results in a smaller annual space heat demand. Better windows allow for a substantial reduction in the insulation level of the opaque envelope elements, too. This example shows that for successfully planning a Passive House, a calculation that takes all these effects into account is highly recommendable - simple rules of thumb will not do.

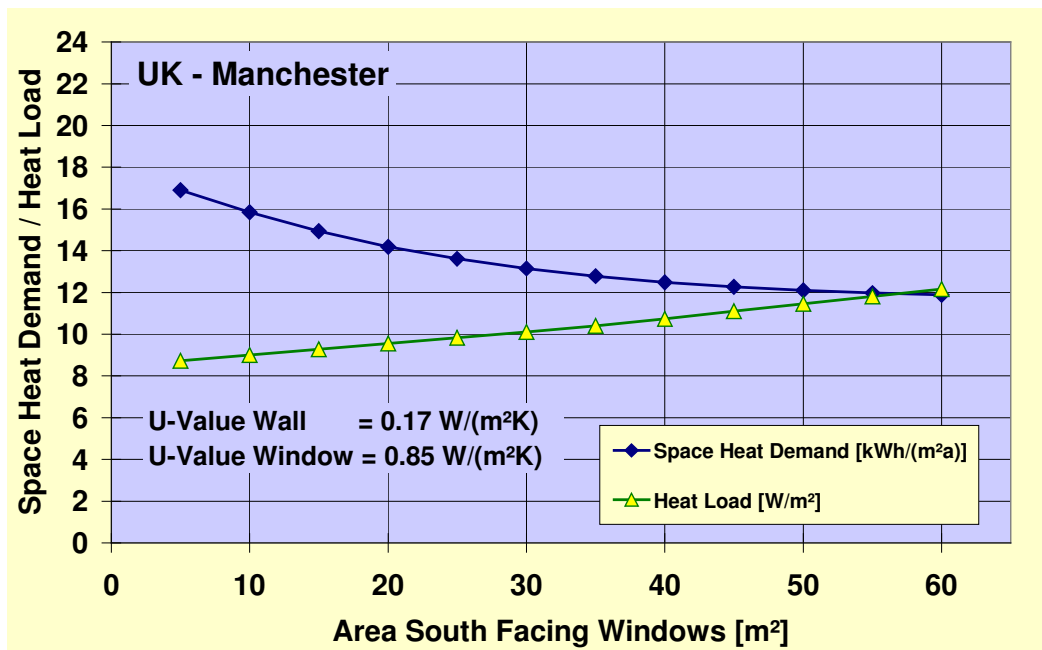
4.3.4 Ireland





Measured data from a year which was claimed to be typical for Birr were used. The Irish climate, like others which are strongly influenced by the gulf stream and the thermal buffer effect of the sea, is a lot milder than the German one. Solar radiation levels in winter, on the other hand, are comparable to Germany. Therefore, a lot less insulation than in Germany is required. Under favourable boundary conditions, south facing windows may achieve high net solar gains.

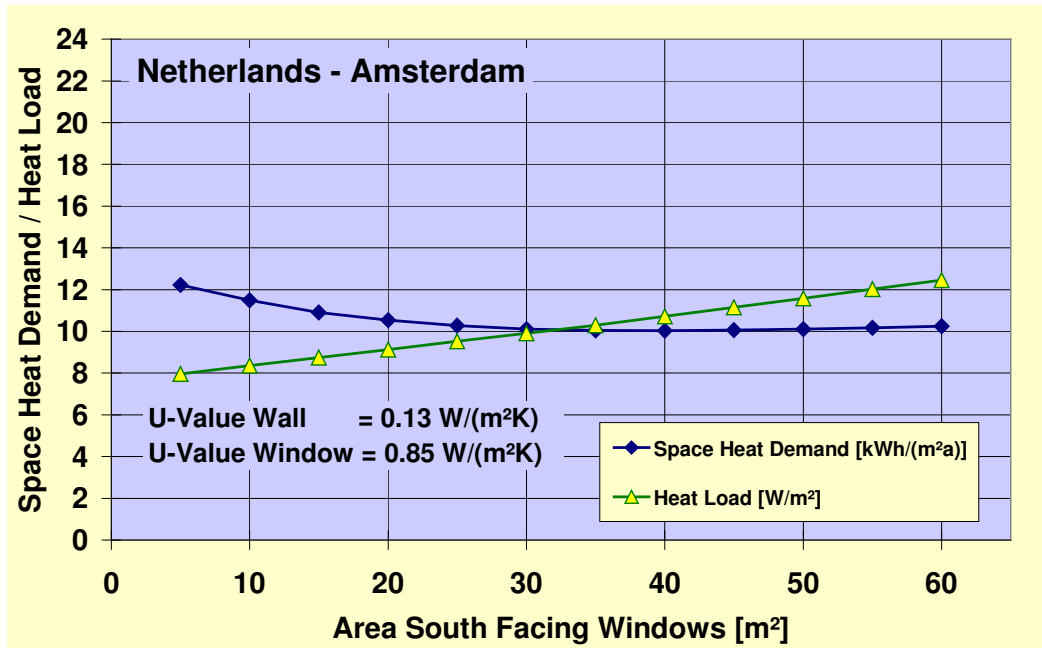
4.3.5 UK



Climate conditions in the UK (TRY Manchester) are very similar to Ireland. The results for Manchester are therefore nearly identical to those of Birr.

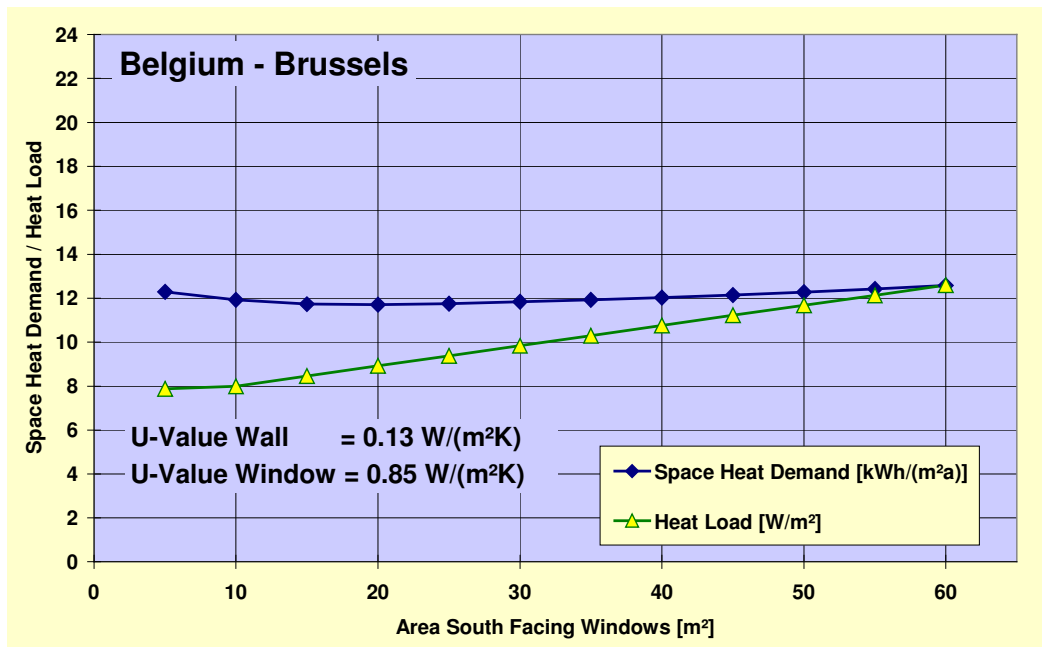


4.3.6 The Netherlands



Amsterdam data were taken from [ASHRAE 2001]. Insulation requirements turned out to be quite comparable to the German reference case.

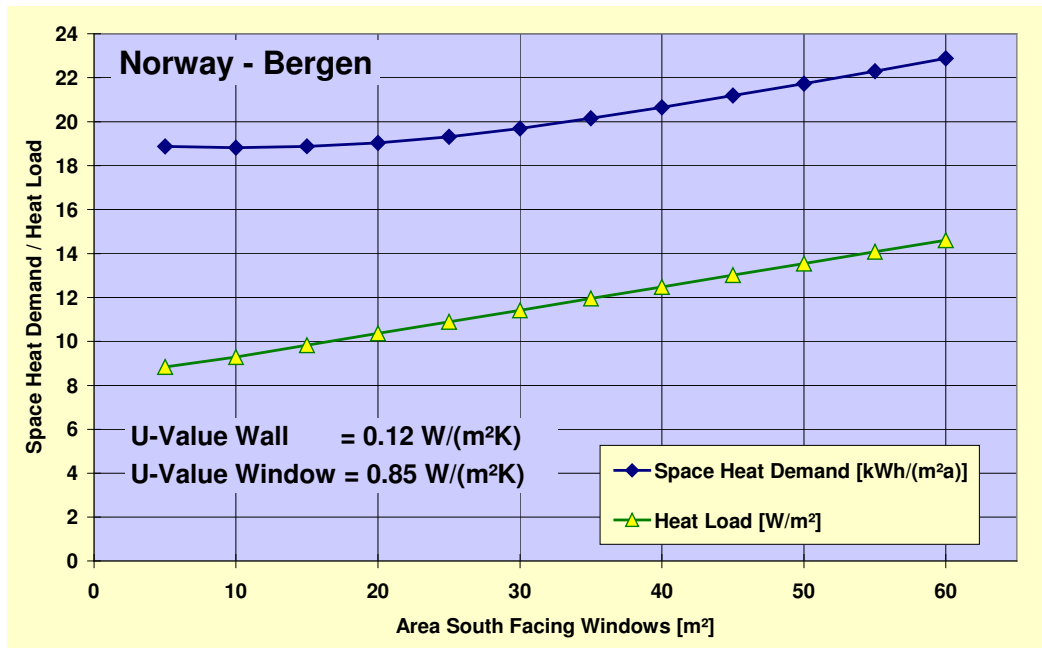
4.3.7 Belgium



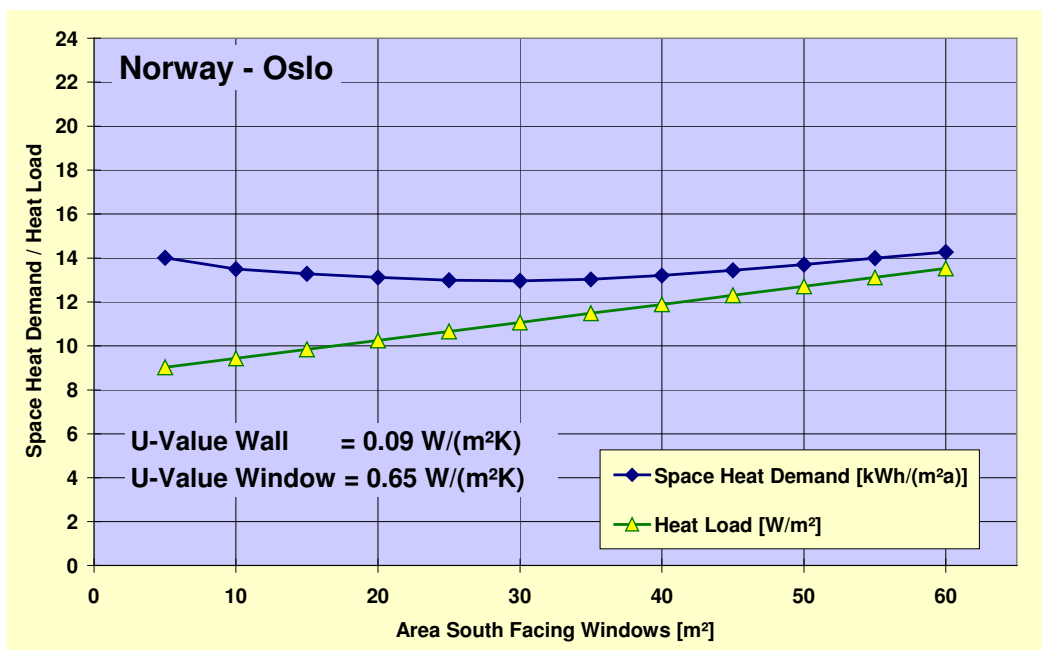
The IWEK data for Brussels are very similar to those for Amsterdam. In general, there is a little less solar radiation; depending on window size, the space heat demand in Brussels may be up to 20% higher than in Amsterdam.



4.3.8 Norway



For Norway, two "Representative Design Years for Solar Energy Applications" from IEA-SHCP, Task 9, were available. The first location, Bergen, is renowned for its high amounts of annual precipitation. Being situated at the North Sea, the climate is a lot milder than at other locations at the same latitude. Insulation levels may therefore be chosen similar to Germany. Due to the low solar radiation, though, small windows are advantageous for minimizing the space heat demand.

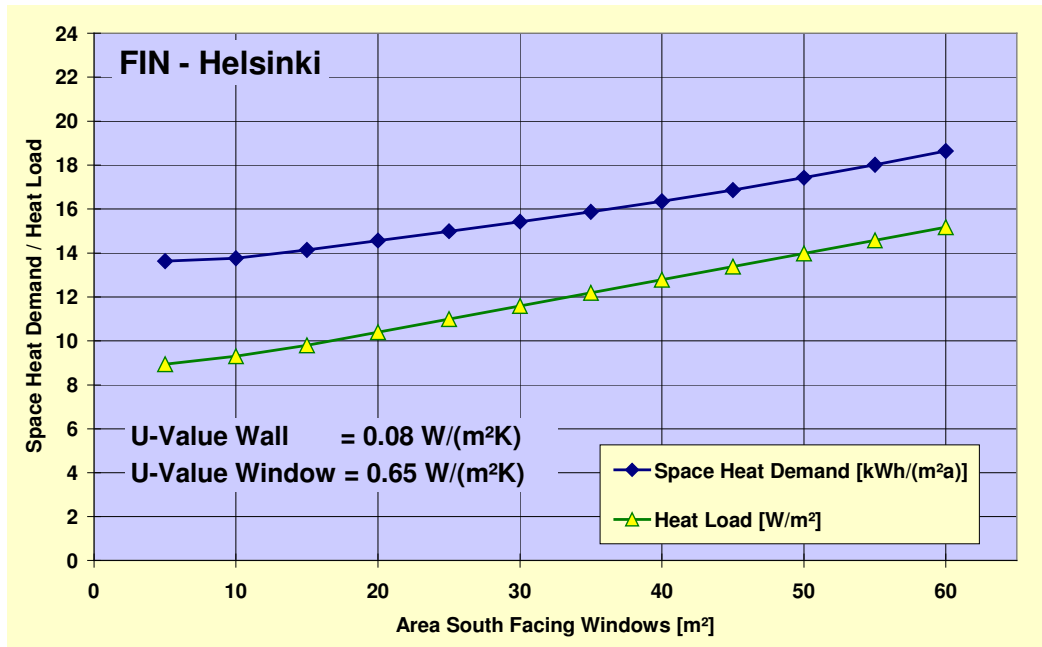


In Oslo, although it may be reached by large, seaworthy vessels, the climate is substantially less maritime than in Bergen. Minimum temperatures during the night may be as low as -25 °C, but there is more solar radiation available than in Bergen.



In order to limit the heat load to 10 W/m², very good insulation and further optimized windows are required.

4.3.9 Finland



Helsinki (IWECC data) combines the difficulties of Oslo and Bergen: Minimum temperatures are comparable to Oslo, but radiation levels are close to zero in December and January. In order to build Passive Houses, extremely good insulation, small, highly insulated windows and a compact building shell will be required unless better components, especially better windows, can be made available.



5 Conclusions

An algorithm for the determination of heat load design data from hourly climate data for typical years has been developed. The proposed corrections to the heat load data based on a typical year have proven to result in buildings which are working even in unusually cold years, but are not overdimensioned.

The application of the results in a country study indicates that in most of the respective climates, Passive Houses can readily be built with components that are already available on the market. In Ireland, the UK and the Benelux countries the climate turned out to be less challenging than in Central and Northern Europe. Only inland climates in Northern Scandinavia, with design temperatures down to $-20\text{ }^{\circ}\text{C}$, appear to pose some difficulties: They may require very compact thermal envelopes, wall and roof U-values significantly below $0.1\text{ W}/(\text{m}^2\text{K})$ and windows with overall U-values of about $0.65\text{ W}/(\text{m}^2\text{K})$.

6 References

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