SOLGAIN - The Contribution of Passive Solar Energy Utilization to Cover the Space Heating Demand of the European Residential Building Stock

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Abstract –This paper describes the methodology and initial results of the European project “SOLGAIN”, supported by the European Commission in the framework of the Non Nuclear Energy Programme THERMIE (Type B Actions). The main goal of this project is to get reliable information about the impact of passive solar energy utilization on the space heating demand of the residential building stock in Europe. The results of the study will serve as a basis for strategies to catalyze increased passive solar energy utilization in the design of new buildings as well as in building renovation.

In a first step, a methodology to derive the passive solar gains was developed. On the basis of available building stock data, for each country a building typology was determined. For each typical building the heat demand, internal and solar gains were calculated according to EN 832.

The initial results of the calculations show, that the solar fraction of the total heat balance of dwellings vary from 10% (Norway) to 17% (Greece).

1. INTRODUCTION

The overall value of passive solar gains of the European building stock is mostly unknown, roughly estimated or only partly available [1], [2]. The contribution of passive solar gains is also missing in all national and European energy statistics.

For getting reliable data of the solar fraction of the total heat balance of dwellings, the European project “SOLGAIN” has been started.

The results of the study will serve as a basis for strategies to catalyze increased passive solar energy utilization in the design of site plans and buildings. Selected strategies serving as examples will be investigated within the project.

The basic passive solar technology is the use of windows (direct solar gain). Scenarios for future developments will also include advanced technologies, such as energy efficient windows as well as solar mass walls using transparent insulation (indirect solar gain).

The developed methodology will be applied to the countries of the partners involved (Belgium, Finland, Germany, Greece, Ireland, Norway, UK). An extension for the EU as a whole and - if requested - for third party countries could easily be applied on the basis of the methodology to be developed. An extension to the topic...
of passive solar energy use in buildings as whole - e.g. daylighting, cooling - may be covered by a follow-up action.

2. METHODOLOGY

For calculating the total passive solar gains for a country, a methodology has been developed, which can be applied to all countries of Europe – regardless to the quality of the available data.

The passive solar gains are depending on a large range of parameters. Of course, all these data are not available for all buildings in Europe. The quality of the statistical data of the existing building stock in the European countries varies. Due to this big differences of the data different methods were developed to come to the total solar gains for the dwellings:

The basis for all methods are typical buildings, from which all necessary information to determine the heat demand and the solar fraction are known: Total number of occurrence, floor area, roof area, glazed area, glazing type, wall, roof and floor type including all layers, orientation, internal gains, user profiles, location and weather.

The calculation of the specific heating demand and solar fraction for a typical building is based on a stationary energy balance procedure (EN 832). This procedure takes into account inner and outer changes of the temperatures and the dynamic change of internal and solar gains. The sum over all typical buildings will deliver the overall heat demand and solar gains.

The way of getting these typical buildings is depending on quality of the available data:

2.1 Bottom Up Method

An overall building typology based on national statistics is available, including all above mentioned building data. Out of these data, the overall heat balance and therefore the solar gains of this typical building can be determined. Building the sum over all building types, the total heating demand of the dwellings can be calculated. This result can be cross-checked with national statistic data for energy consumption in households.

2.2 Upscaling Method

The building classification is only available for one area of the country. For getting data for the entire country, a realistic upscaling factor for each building type has to be determined. Different building types, weather conditions, insulation standards and usage should be taken into account. The results of the calculations have to be cross-checked with national statistic data for energy consumption in households. In the case of deviations, the upscaling factors have to be adapted.

2.3 Top-Down Method

No detailed information about the building stock is available at all. In this case, the national statistical data for the total dwelling heating demand is the basis for a useful estimation of the typical buildings. All available data should be taken into account, making the estimation as realistic as possible. A cross-check is not possible.

3. BUILDING CLASSIFICATION

A common housing stock classification has been developed, which can be used across the European countries. The resulting classification is used to provide the input data/characteristics for the calculations. This classification needs to split the housing stock into a reasonable number of representative groups, such that the total number of energy calculations for each country is not excessive. The classification must also apply across Europe, taking into account climate and construction differences, and using existing statistical data.

The classification has to take into account on one hand all important factors, which influence the solar gains significantly and on the other the availability of the data. Based on the information received from the involved countries, the proposed classification is according to:

- Location conditions (climate and solar radiation)
- Building type (built form & thermal properties)
- Building age (built form & thermal properties)
- Energy improvements – (thermal properties)
3.1 Building Location
The solar radiation incident on a country’s housing stock depends on the country’s climate. Given that there is quite extensive weather data for most countries in Europe, in particular data on incident solar radiation and ambient temperature, it was decided that it is more appropriate to classify the building location according to each country under consideration. For each of the countries involved in the SOLGAIN project, the country’s partner in the project deemed it appropriate to use a single typical/average climate to cover that country’s housing stock, with the exception of Greece where two very distinct climates exist and it was thought necessary to account for both.

3.2 Building Age
Using housing age as a classification is a useful way of grouping housing into manageably sized groups. The age of a dwelling will usually indicate the type of construction used and the insulation standards since these will be related to the regulations in force at the time. Age is also a good indicator of window size, since this is related to building regulations and to changing building fashions. These factors have a significant impact on the space heating demand for a dwelling and the solar contribution.

The survey of existing statistical data available conducted by ECD confirms that information is available in each of the partner countries regarding the age profile of the housing stock. However, the age bands for which data is available in partner countries are not the same. Due to this variation it was decided that the most workable option is for the classification to use country specific age bands, chosen by each country according to the statistical data available to them. This avoids each country having to manipulate their existing data to fit a fixed set of age bands.

3.3 Building Type
The house type is a useful classification to make as it dictates the built form and is an important factor in determining the floor area, window size and space heating energy demand. Available house types differ among the partner countries but could be broadly classified as detached house, terraced house or apartment block. Similar to the age band classification above it was decided that each country should classify their house types according to the statistical data they have available.

3.4 Energy improvement level
The level of insulation in a dwelling is an important factor in determining the energy consumption for space heating in the dwelling. It is also a contributory factor to determine how much of the solar energy gained is actually useful energy. In the summer, solar gain will not be of significant use in either a well or a poorly insulated dwelling, so long as the external ambient temperature is sufficient to achieve minimum thermal comfort levels (say at least 15°C). Space heating is not required in Summer because the ambient temperature is high enough, so for the purposes of SOLGAIN it has been decided to examine only the heating season (as applicable to each participating country). During spring and autumn, when solar gain is available and there is a heating demand, the usefulness of solar energy will potentially be greater in a poorly insulated house since the overall demand for heating is higher and almost all solar energy entering a dwelling is useful, compared to a well-insulated house where some of the available solar energy may exceed the heating requirement and therefore not be deemed useful. The overall demand for space heating energy to achieve a given level of comfort in a poorly insulated house will be higher than that for a well-insulated house. Therefore while the total useful solar energy may be higher for a poorly insulated dwelling, its contribution (in percentage terms) to space heating energy demand for the dwelling is likely to be lower.

Information on the insulation level for each of the housing classifications may not be available in existing statistics, requiring calculations to be made based on the prevailing building standards at the time of construction and/or surveys. Calculations also have to be made regarding the number of houses that have undergone energy improvements. A house with a package of energy improvements will have a lower energy demand.

In practice the project partners approached this issue differently depending on what information they had available for their country. For the UK, the calculations focused on the quality of the thermal envelope for the UK housing stock as a whole aiming to derive reasonable average values for the floor, roof, wall and glazing U-values for each of the ‘house type + age’ categories in the classification. Germany, Belgium and Greece adopted a similar approach. Norway further subdivided each ‘house type + age’ category according to the thermal improvements which had been made to the building envelope.

3.3 Example data for classification: West Germany
As an example, in following table the main classified data of the building stock of former West Germany are presented. The same type of data has been also processed for Norway, Finland, UK, Ireland, Germany East, Belgium and Greece.

![Fig. 2: Methodology to classify the building stock](image-url)
### Table 1: Main data of the building classification for former West Germany. The values are:

<table>
<thead>
<tr>
<th>Building type</th>
<th>No. [1000]</th>
<th>$A_{floor}$ [m²]</th>
<th>$A_{window}$ [% of $A_{floor}$]</th>
<th>Persons</th>
<th>Vent. [1/h]</th>
<th>$u_{floor}$ [W/m²K]</th>
<th>$u_{roof}$ [W/m²K]</th>
<th>$u_{wall}$ [W/m²K]</th>
<th>$u_{glazing}$ [W/m²K]</th>
<th>Internal [kWh/m²]</th>
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<td></td>
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<td>.6</td>
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<td>0.91</td>
<td>3.3</td>
<td>43.8</td>
</tr>
</tbody>
</table>

1 Source: IKARUS database[4].

- **No.** : Number of buildings in country in thousands
- **$A_{floor}$** : Floor Area of building
- **$A_{window}$** : Window Area of building
- **Persons** : Number of persons in building
- **Vent.** : Air change rate in 1/h
- **$u_{floor}$** : $u$-value of floor
- **$u_{roof}$** : $u$-value of roof
- **$u_{wall}$** : $u$-value of wall
- **$u_{glazing}$** : $u$-value of glazing
- **Internal** : Total internal loads including persons
3. INITIAL RESULTS

All construction data together with the climatic conditions have been used as input for the simulation. Following outputs have been calculated for each country:

- Total Heat demand per building (kWh)
- Solar gains per building (kWh)
- Utilization factor for solar and internal gains (-)
- Internal gains per building (kWh)
- Total heat demand, for the overall amount of buildings $Q_{\text{heating}}$ (GWh)
- Total internal gains $Q_{\text{internal}}$ (GWh)
- Total solar gains $Q_{\text{solar}}$ (GWh)

Finally, the “Solar Fraction” $f_{\text{solar}}$ can be determined out of these results:

$$f_{\text{solar}} = \frac{Q_{\text{solar}}}{Q_{\text{heating}} + Q_{\text{internal}} + Q_{\text{solar}}}$$

In table 2 are shown initial\(^2\) results of the solar fraction.

<table>
<thead>
<tr>
<th>Country</th>
<th>Solar Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>10 %</td>
</tr>
<tr>
<td>UK</td>
<td>16 %</td>
</tr>
<tr>
<td>Belgium</td>
<td>11%</td>
</tr>
<tr>
<td>Greece</td>
<td>16%</td>
</tr>
</tbody>
</table>

Table 2: Initial data for the solar fraction

\(^2\) The data for the missing countries are actually cross-checked. For Germany we found some errors in the database [4], which will be corrected in cooperation with its author in spring 2000.

4. FOLLOW UP WORK IN THE PROJEKT

4.1 Environmental Impact

Energy saving data, equal to the utilized solar gain data, will be converted to reductions of emissions (CO\(_2\), SO\(_2\), NO\(_x\)) and nuclear waste/risk. In this calculation the heating system and its energy source for the building classes and the countries will be considered. Energy savings and emission reduction data will be summarized by country.

The method for calculation of total emission reduction due to utilized solar gains in the dwelling stock is shown in figure 3.

4.2 Economic Value

To quantify the economic value of the passive solar gains in residential buildings, energy savings will be converted into cost savings. The economic value depends on the cost of the energy per unit delivered, the amount of secondary energy used for heating and the seasonal efficiency of the heating system. The economic data will be summarized per country.

The methodology to be used will be similar to the one used for the environmental impact.

4.3 Scenarios for future developments

Scenarios for future developments will also include advanced technologies, such as energy efficient windows as well as solar mass walls using transparent insulation (indirect solar gain).
5. CONCLUSIONS

A methodology to derive the passive solar gains for the existing building stock was developed. On the basis of available data, for each country a building typology was determined. For each typical building the heat demand, internal and solar gains were calculated according to EN 832. The first results of the calculations show, that the solar fraction of the total heat balance of Europeans dwellings vary from 10% (Norway) to 17% (Greece).

The results of all participating countries will be presented at the conference.
The printed version of the final results including the environmental impact, economic value and scenarios will be available on request at the end of 2000 from the author.

REFERENCES