CO_2 Emission and Energy Saving Potential through Correct Pipe Insulation of Space Heating and Domestic Hot Water Distribution Systems in the New and Existing Buildings

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ABSTRACT

In March 2003 a "CO_2 - Saving Potential when using Pipe Insulation" study [1], sponsored by Armacell - worldwide producer of flexible pipe insulation products, was published by the Centre for Environmentally Sustainable Buildings (ZUB) in Kassel. The aim of the study was to answer how much energy and CO_2 emission can be saved with optimal pipe insulation installed on accessible space heating and domestic hot water distribution pipelines in existing old buildings and on all pipelines in the new buildings. It revealed astonishing numbers of 70% saving potential in the old houses.

This paper - done by Armacell on its own - is a continuation of the ZUB-Study with extension to all major European locations and based on European and international standards. The results confirm the previous ones: in mild European climate even well insulated distribution pipelines yield anually additional, not recovered heat losses being 10% of the energy generated for space heating; with poor insulated pipelines this result grows up to 25%. Even higher heat losses, especially from domestic hot water pipelines, were received for southern locations. The saving potential of CO_2 emission is some 3,1 kg/($m^2 \cdot a$) ≅ 500 kg/a for a 160 m^2 single family house.

KEYWORDS

pipe insulation, CO_2 emission, CO_2 savings, distribution pieplines, energy efficiency.

INTRODUCTION

Usually when it comes to energy savings in buildings it is structural insulation of walls and roof as well as thermal transmission properties of windows which are taken into consideration in the first step. However, optimal pipe insulation of space heating and domestic hot water distribution systems in the new and existing buildings is still a remaining potential for even further reduction of energy use and thus for reduction of the CO_2 emission at reasonable cost in many cases.

The purpose of this paper is to present results of the study which insisted in standardized calculation of heat losses from pipework and their infuence on energy required in a building for seasonal winter heating. The calculations were done for the 6 single-family houses placed in 6 different European geographical locations with integrated local design approach as e.g. wooden house for Scandinavia or 15° angle, flat roof house for southern location (Spain).

CALCULATIONS

Sequence of calculations

In principle all calculations concerning heat losses $\mathbf{Q_L}$ due to the house structure were done in accordance with ISO 13790 [3]. They include:

- transmission heat losses through a building shell of the house,
- heat transfer via the ground,
- ventilation heat losses.

The ISO 6946 [7] and EN ISO 13370 [6] were used for particular calculations. Heat gains $\mathbf{Q_g}$ were also calculated in accordance with ISO 13790 and they included:

- internal heat gains (metabolic + from appliances),
- solar gains through glazing i.e. windows,
- additional internal heat gains (from space heating and dhw distribution pipes).

The approach of including the heat losses from space heating and domestic hot water pipework is in line with the recent draft of the ISO 13790 (prEN ISO 13790: May 2005, clause 10.1 [4]). Heat losses and gains yield gain/loss ratio γ.

Further, also in accordance with the ISO 13790 the internal heat capacity of the building **C** and based on it the time constant τ were calculated. Finally, based on these values the utilisation factor η (of the heat gains) was calculated. The utilisation factor is decisive for the further evaluation of significance of the heat losses from the pipework and their split into recovered (and thus utilised for space heating in winter) and not recovered (and thus eventually lost) heat losses.

Heat losses from space heating and domestic hot water pipework were calculated in accordance with prEN 15316-1 [9] and its particular parts [10] and [11]. For each house 3 scenarios of different pipe insulation thickness were taken into consideration. In general it was assumed that optimal pipe insulation on heating pipelines equals approximately pipe diameter and on domestic hot water pipelines is even 50% bigger (heat losses all the year round, not only in winter; in summer in 100% not recovered; such approach can be confirmed through economical calculations [2]). Not optimal pipe insulation thickness was assumed as roughly half of the optimal one except for individual branching pipelines to the radiators $\mathbf{L_A}$ and hot water tapping outlets $\mathbf{L_{SL}}$. The last scenario is no pipe insulation at all or poor insulation effect (e.g. foil wrap), which is assumed to give the same effect as 2 mm of pipe insulation (dust over a bare pipe, some air gap around it etc.). All 3 scenarios together with the lengthes of the pipes calculated in accordance with the prEN 15316-2-3 and prEN 15316-3-2 are presented in the Table 1.

For each scenario of pipe insulation the final energy required (energy demand needed to be generated) for space heating as well as not recovered (additional) heat losses from space heating and domestic hot water distibution pipelines were calculated. Not recovered heat losses from domestic hot water distibution pipelines were calculated separately during winter heating season (when they are only partially not recovered) and in summer (when they are 100% not recovered) and then added together. Based on this it was possible to calculate further results like: CO_2 emission, fuel consumption and cost as well as their saving potential when optimal pipe insulation was compared with the poor one.

Table 1
Three scenarios of pipe insulation thickness on distribution pipelines

system	pipe location (zone)	pipe diameter [mm]	pipe length [m]	insulation thickness [mm]		
				optimal insulation	not optimal insulation	poor / no insulation
heating	V	28	34,0	20	9	2
heating	S	22	17,6	13	6	2
heating	A	15	143,5	9	2	2
dhw	V	22	29,2	30	9	2
dhw	S	18	12,0	25	9	2
dhw	SL	12	12,0	20	6	2

Assumptions and input data applied

A typical, stand-alone, single family, two-storey, 45° roof angle, 160 m^2 net floor area, modern, well insulated house was assumed for the calculation. Density and specific heat capacity of construction materials were taken from prEN ISO 10456 [8]; Table 3 and Table 4. Thermal conductivity for the majority construction materials was also taken from the same standard as well as from the other standards, handbooks and technical data published by producers. Seasonal calculation method was chosen from the methods offered by the ISO 13790. According to the clause 6.1. no division into different normal and reduced heating periods was applied. Conventional input data according to Annex K of the ISO 13790: indoor temperature +20°C and internal heat gains 4 W/m^2 were assumed. Air change rate was assumed as 0,6 h^{-1} from the Table G.3 for moderate shielding and medium thightness of the building.

For southern location in Spain a flat roof house (15° roof angle) with less structural wall insulation and smaller south façade windows was assumed. For Nordic location in Sweden a wood-construction house typical for this area was assumed as well.

Solar gains through glazing were calculated in accordance with the clause 8.2, F.5.1 and Annex H of the ISO 13790. Typical correction factors were applied, no shading from horizon (background) was assumed. Solar irradiation and outdoor temperature for each geographical location (including orientation and roof inclination angle) were obtained through internet from the European Joule Programme at www.soda-is.com [13] as monthly means of daily irradiation [kWh/m^2]. Comparison of outdoor temperature and limit heating temperature calculated for each month in accordance with the ISO 13790, clause 10.2 allowed to calculate duration of the heating season.

Standard up-to-date pipe insulation was assumed with its thermal conductivity 0,040 W/(m·K) at +40°C. 15% pipe length allowance was added to cover thermal bridge effect of pipe fixing. Heat gains from auxiliary equipment of space heating and domestic hot water systems, like e.g. circulation pumps were neglected. Efficiency of the generator (boiler) for both space heating and hot water production was assumed as 90%. Domestic hot water system was assumed as the one with circulation with its default temperature of 60°C (circulation loops) and 32°C (individual spurs) according to the prEN 15316-3-2, clause E.5 were assumed.

CO_2 emission factor was assumed as 0,270 kg/kWh of energy contained in the fuel (oil) in accordance with the standard prEN 15315, Table A.2 [12].

Iterative calculation

Annual recovered heat losses from space heating and domestic hot water distribution pipelines according to the Equation 1.

$$Q_{recovered} = \eta \cdot (Q_{th} + Q_{tw}) \text{ [kWh]} \qquad (1)$$

where:
η – utilisation factor
Q_{th} – annual total heat losses due to the space heating distribution system
Q_{tw} – total heat losses due to the dhw distribution system during heating period

depend on the utilisation factor η which in its turn depends on the gain/loss ratio γ being strictly infuenced by the heat gains including the above mentioned recovered heat losses from distribution pipelines. This creates a loop in the calculations which must be solved in iterative way with consecutive adjustment of the utilisation factor value.

RESULTS

Results were calculated for the following locations, presented in the Table 2.

Table 2
Locations and their basic parameters

country	city	geogr. latitude	geogr. longtitude	assumed min. ambient temp. in winter	average outdoor temperature during heating season	heating season	remarks
				[°C]	[°C]	[days]	
Sweden	Stockholm	59°	18°	-22	3,1	254	wooden house
Poland	Warsaw	52°	21°	-20	3,1	233	
Germany	Münster	52°	7,5°	-18	5,6	233	
England	Manchester	53,5°	-2°	-16	6,6	259	
Italy	Milano	45,5°	9°	-14	5,7	196	
Spain	Madrid	40,5°	-4°	-10	8,5	201	15° flat roof

Comparison of additional, not recovered heat losses with the energy which needs to be generated for space heating is presented in the Figure 1 in [$W/m^2 \cdot a$]. The not recovered energy contains 100% heat loss from domestic hot water distribution pipelines in summer. That is why it is relativly high in southern locations (Spain, Italy) due to their short heating period. Proportional relation of the not recovered heat losses to the energy generated (required) for space heating is presented in the Figure 2. Even for the optimal pipe insulation thickness it amounts to some 10% for the mild climate location. About 70% these losses are due to the domestic hot water distribution pipelines, especially with circulation as assumed in this case.

The split of annual not recovered heat losses due to space heating and domestic hot water distribution pipelines is presented in the Figure 3. Almost the same values of the not recovered heat losses from space heating distribution pipelines for so distant locations as Italy, Spain, Germany and Poland are result of different utilisation factors which show tendency to balance the winter ambient temperature and heating period difference when calculating the heat losses.

Figure 1
Not recovered heat losses vs energy generated for space heating

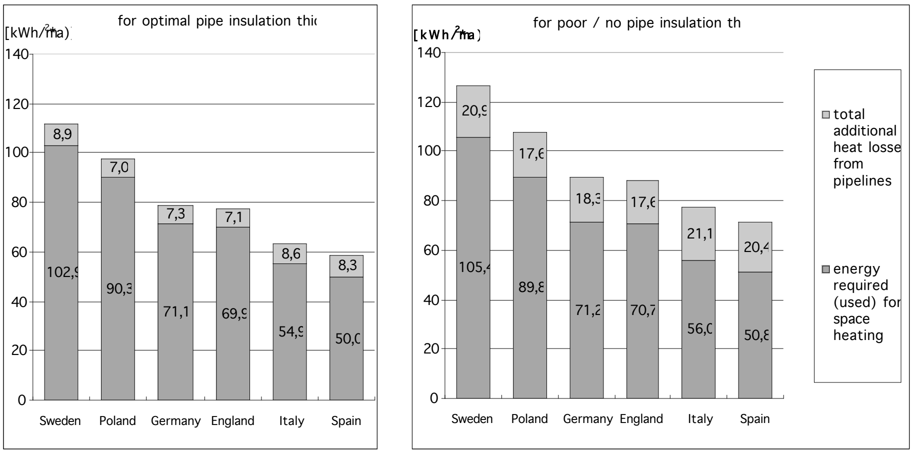


Figure 2
Proportional relation of the not recovered heat losses to the energy generated for space heating

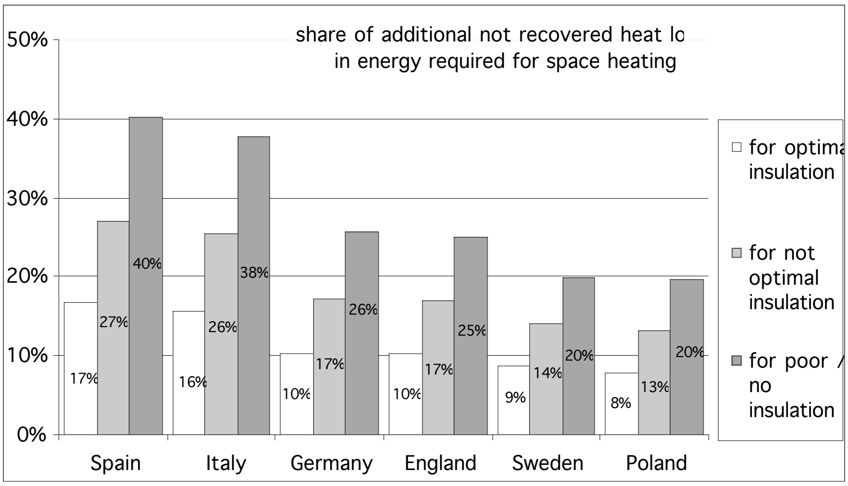


Figure 3
Not recovered (additional) heat losses from space heating and dhw distribution pipelines

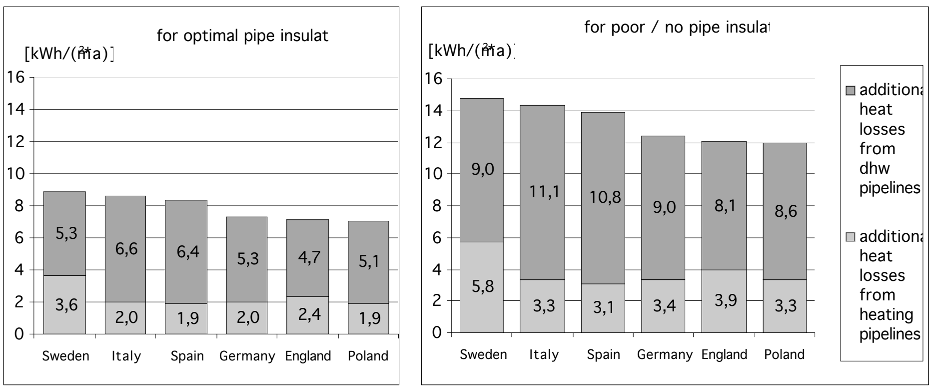
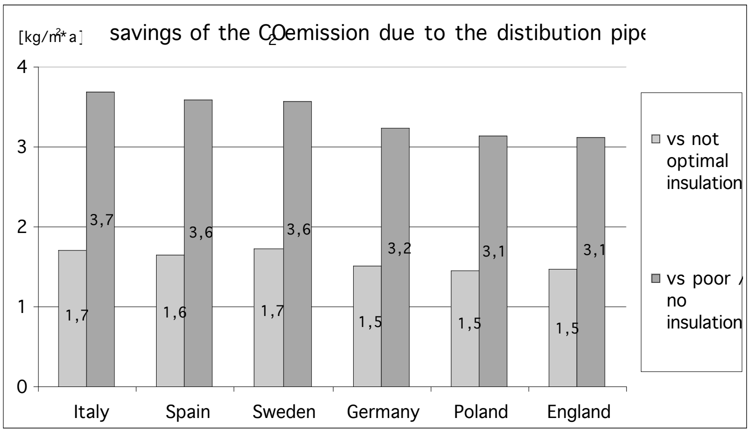


Figure 4 shows that the optimal pipe insulation helps to reduce the CO_2 emission due to the not recovered heat losses from the distribution pipelines by more than half in comparison to no or poor pipe insulation. This shows saving potential in retrofitting measures which can be applied in existing building, even if only some part of the distribution pipelines can be insulated.

Figure 4
Savings of the CO_2 emission.



CONCLUSIONS

- Contrary to common belief also for pipelines totally located in heated spaces there is some additional heat loss (between 13% and 22%) and they should be insulated.
- Vast majority of not recovered heat losses (between 60% and 77%) are due to the 100% heat losses from dhw pipes in summer and particulary these pipes should be especially well insulated.
- Heat losses from pipelines might be significant and can neither be forgotten during design phase nor assumed as a coefficient in a lump-sum way. They should be calculated in detailed way, especially for the new houses.

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