# High Return on Investment with Environment Protecting Insulation Layer Thicknesses

**FESI document 6**

FEDERATION EUROPEENNE DES SYNDICATS D'ENTREPRISES D'ISOLATION

EUROPEAN FEDERATION OF ASSOCIATIONS OF INSULATION CONTRACTORS

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# FESI DOCUMENT 6: High Return on Investment with Environment Protecting Insulation Layer Thicknesses

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**Executive Summary**

This paper seeks to show that a consideration of pay-back periods indicates that the reduction of heat losses as a result of applying thermal insulation is a cost-effective and economic way to save energy.

In addition, the pay-back period increases insignificantly when the insulation layer is increased over and above the economic thickness up to the ecological thickness. Therefore environment protection through insulation is very cost effective.

So a small additional effort can provide a significant contribution to $CO_2$ reduction.

## 1. Additional costs for an "environment protecting" insulation layer thickness

Tables 1 and 2 demonstrate in an exemplary fashion the variations in the overall costs (ΔKG) for a reduction of heat losses in a mineral wool insulation system. Basis of the calculations is an interest rate of 5 % and an annual energy expenditure increase of 6 %.

| W = 6 €/GJ | | | | | | |
|---|---|---|---|---|---|---|
| DN | $\vartheta_M$ °C | sw mm | s* mm | ΔKW % | ΔKis % | ΔKG % |
| 50 | 50 | 30 | 50 | -25 | 17 | 4 |
| | 100 | 50 | 80 | | 30 | 5 |
| | 300 | 100 | 190 | | 106 | 18 |
| | 500 | 150 | 320 | | 199 | 35 |
| 150 | 50 | 40 | 60 | -25 | 20 | 3 |
| | 100 | 70 | 100 | | 29 | 4 |
| | 300 | 140 | 230 | | 79 | 13 |
| | 500 | 200 | 350 | | 117 | 18 |
| 500 | 50 | 60 | 80 | -25 | 14 | 3 |
| | 100 | 100 | 140 | | 25 | 5 |
| | 300 | 200 | 300 | | 50 | 9 |
| | 500 | 290 | 450 | | 69 | 12 |

***Table 1: Cost increase to reduce heat loss by 25 % at a heat price***

Explanation:
DN 150; medium temperature 100 °C

In the left part of Table 1, the economic insulation layer thicknesses (sW) according to VDI 2055 and the increased insulation layer thicknesses (s*) have been given.

In the right part of Table 1, the percentage variation of the respective costs is given: The heat loss costs KW decrease by 25 % ( □KW). The insu
17 % up to 200 % ( □Kis).

The overall costs ( □KG) – given in the last column – show a notably lesser increase. The increase rates are between 3 % and 35 %.

The results show that saving energy through an improved heat protection is a comparatively economic and profitable measure.

| W = 10 €/GJ | | | | | | |
|---|---|---|---|---|---|---|
| DN | $\vartheta_M$ °C | sw mm | s* mm | ΔKW % | ΔKis % | ΔKG % |
| 50 | 50 | 40 | 60 | -25 | 18 | 3 |
| | 100 | 70 | 120 | | 55 | 14 |
| | 300 | 130 | 260 | | 152 | 27 |
| | 500 | 180 | 390 | | 232 | 34 |
| 150 | 50 | 60 | 90 | -25 | 30 | 8 |
| | 100 | 90 | 140 | | 48 | 9 |
| | 300 | 180 | 310 | | 106 | 19 |
| | 500 | 250 | 460 | | 150 | 23 |
| 500 | 50 | 70 | 100 | -25 | 21 | 3 |
| | 100 | 120 | 170 | | 30 | 4 |
| | 300 | 250 | 380 | | 60 | 10 |
| | 500 | 350 | 560 | | 83 | 12 |

***Table 2: Cost increase to reduce heat loss by 25 % at a heat price***

## 2. Pay-back period (PBP)

Despite these results, the question is raised whether the increased investment costs can be justified.

To assess the profitability of an insulation investment, the investment costs must be put into relation to the energy costs avoided.

A measure of the profitability is the pay-back period, also called capital return time. This is the period in which the expenditure for the investment is offset by the savings in heat loss costs. It is calculated with the relation.

$$PBP = \frac{Investment\ \exp enditure}{annual\ savings}$$

Table 3 shows the calculation of a pay-back period with the example of a pipe of DN 150 and a medium temperature of 100 °C with an economic insulation layer thickness of 70 mm and an ecological insulation layer thickness of 100 mm with an assumed heat price of 6 €/GJ. For this, the pay-back period is roughly 0, 62 years.

| | | | | |
|---|---|---|---|---|
| *Pay-back period* | | | *PBP* | *PBP** |
| *Piping DN 150* | $\vartheta_M$ | : | 100 °C | 100 °C |
| *Heat loss without insulation* | $Q_0$ | : | 0,453 kW/m | 0,453 kW/m |
| *Heat loss with insulation* | Q | : | 0,03 kW/m | 0,022 kW/m |
| *Savings* | | : | 0,423 kW/m | 0,431kW/m |
| *Savings per year (ß = 8760 h/a)*[1)] | ΔQ | : | 3705 kWh /(m · a) | 3775 kWh /(m · a) |
| *Costs for thermal energy W (6 €/GJ)* | W | = | 0,0216 €/kWh | 0,0216 €/kWh |
| *Annual saving* | | : | 80 €/ (m · a) | 81,5 €/ (m · a) |
| *Pay-back period* | KRZ *PBP* | = | 0,62 a (= 7,44 Monate) | 0,79 a ( = 9,5 Monate) |

[1)] β = jährliche Betriebsstunden/*annual operation time*

***Table 3:** **Calculations for the determination of pay-back periods PBP and PBP****

Means that the capital invested in this example has been returned already after roughly 7,44 months. Such a short pay-back period, also called amortisation time, shows that insulation is a highly profitable product. Its profitability is probably not outmatched by any other industrial investment.

Tables 4 and 5 show the pay-back periods for pipe insulations for the economic insulation layer thickness according to VDI 2055 (PBP) and for the increased insulation layer thickness to achieve an additional 25 % energy saving (PBP*) at heat prices of, respectively as well as the difference ΔPBP.

| W = 6 € / GJ | | | | |
|---|---|---|---|---|
| DN | $\vartheta_M$ in °C | KRZ PBP in a | KRZ* PBP* in a | ΔKRZ ΔPBP in a |
| 50 | 50 | 3,14 | 3,52 | 0,38 |
| | 100 | 1,02 | 1,29 | 0,27 |
| | 300 | 0,25 | 0,51 | 0,26 |
| | 500 | 0,15 | 0,43 | 0,28 |
| 150 | 50 | 1,69 | 1,97 | 0,28 |
| | 100 | 0,62 | 0,79 | 0,17 |
| | 300 | 0,17 | 0,30 | 0,13 |
| | 500 | 0,09 | 0,20 | 0,11 |
| 500 | 50 | 1,54 | 1,72 | 0,18 |
| | 100 | 0,54 | 0,67 | 0,13 |
| | 300 | 0,14 | 0,21 | 0,07 |
| | 500 | 0,07 | 0,12 | 0,05 |
| | | | | |

***Table 4: Pay-back periods PBP for the economic insulation layer thickness according to VDI 2055 and PBP* when reducing the heat loss by further 25 % and their difference*** □*KRZ for a* ***heat price of W = 10 € / GJ***

| W = 10 € / GJ | | | | |
|---|---|---|---|---|
| DN | $\vartheta_M$ in °C | KRZ PBP in a | KRZ* PBP* in a | ΔKRZ ΔPBP in a |
| 50 | 50 | 1,98 | 2,26 | 0,28 |
| | 100 | 0,71 | 1,08 | 0,37 |
| | 300 | 0,20 | 0,49 | 0,29 |
| | 500 | 0,11 | 0,36 | 0,25 |
| 150 | 50 | 1,18 | 1,50 | 0,32 |
| | 100 | 0,44 | 0,64 | 0,20 |
| | 300 | 0,13 | 0,28 | 0,15 |
| | 500 | 0,07 | 0,19 | 0,12 |
| 500 | 50 | 0,98 | 1,16 | 0,18 |
| | 100 | 0,36 | 0,47 | 0,11 |
| | 300 | 0,10 | 0,16 | 0,06 |
| | 500 | 0,05 | 0,10 | 0,05 |

***Table 5: Pay-back periods PBP for the economic insulation layer thickness according to VDI 2055 and PBP* when reducing the heat loss by further 25 % and their difference ΔKRZ for a heat price of*** **W = 10 € / GJ**

Tables 4 and 5 show in the third column the pay-back periods of an economic insulation layer thickness according to VDI 2055 [5]: They are the shorter, the higher the medium temperature.

In the fourth column of Tables 4 and 5 the respective pay-back periods for insulations are shown which have been increased over and above the economic optimum to achieve a further 25 % reduction of energy expenditure. They are only just longer as it is shown in the sixth column.

## 3. Background

The expenditure of fossil energy not only exhausts the available resources of primary energy, it moreover constitutes a strain on the environment through the associated emission of carbon dioxide.

CO2 in the atmosphere absorbs the thermal radiation emitted from the surface of the earth, thereby reducing the heat transfer into space. With a further increasing CO2 content in the atmosphere (Figure 1), a global temperature increase, known as the "green house effect", with changes in the world's climate and other yet unpredictable consequences becomes likely.


*Concentration of carbon dioxide in ppm (parts per million, one thousands 0/00*

**Figure 1: Development of CO2 concentrations in the atmosphere [1+2]**

CO2 originates when carbon is burned, e. g. to create heat. No holdback technology exists for CO2 which could be used at a grand scale as is the case for sulphur or nitrogen oxides which can be filtered out of the exhaust in flue-gas purification installations. Research has been intensified recently under the catch phrase CCS (Carbon-Capture-Storage) to find means and ways to store the CO2 created in combustion processes [3], however, expectations of success are yet unclear. The problem is aggravated by a considerably bigger energy demand for capture and storage. The most effective influence man can exert on the CO2 content of the atmosphere of the earth is by not creating CO2 in the first place.

It is therefore of paramount importance to achieve a reduction of CO2 emissions through savings in the consumption of fossil energy sources. Heat retention is a significant contribution to this.

Against the background of significant energy price increases, the efficient handling of electric power and heat has never repaid as fast as is the case today.

Figure 2 shows the price development of the most important primary energy sources over recent years.

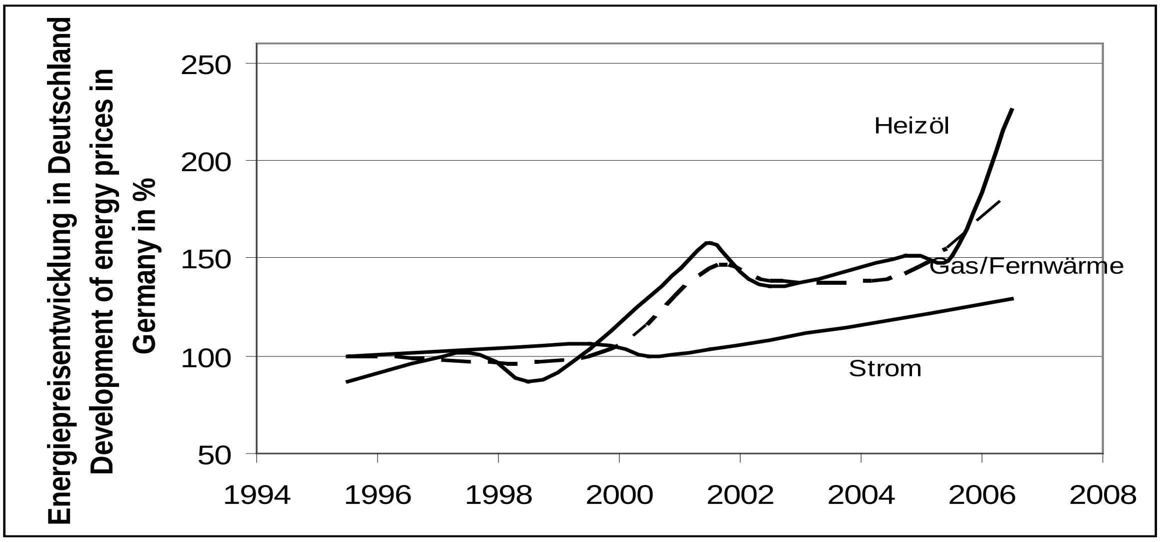


***Figure 2: Price development for primary energy sources (Source: Statistisches Bundesamt)***

Since further increasing energy prices must be reckoned with in the foreseeable future, lacking knowledge regarding energy saving potentials will in the long term lead to higher costs and reduced profits when running industrial installations.

## 4. Subject of this Document

In this document, the discussion of ecologically advised insulations to reduce energy consumption and to protect the atmosphere is related to the insulations of industrial installations.

It provides a general discussion of the technical issues. It does not replace detailed calculations and assessments of prevailing physical conditions in complicated building tasks. It is a publication of the Technical Commission of the BFA WKSB and gives information about the status of technology at the moment of publication.

The insulation effort, which needs to be invested in an industrial installation (insulation investment), may be determined under the following aspects:

Design related to:

- operating aspects: securing of production processes
- Condensation prevention on cold installations
- Aspects of working safety and personnel protection
- pre-set maximum heat loss
- Economic aspects: the most cost effective relation between insulation investment and resulting long-term energy savings
- Ecological aspects

This letter discusses insulation investments under economic and under ecological aspects. It deals with the related pay-back periods for the insulation investment. Starting from this aspect, it explains the additional expenditure and their related slightly longer pay-back periods when the economic optimum is exceeded for ecological reasons: CO2 savings, climate protection. It is meant to explain the following:

- Investments for heat retention measures have very short pay-back periods.

- increased insulation layer thicknesses beyond the optimum calculated according to VDI 2055 to achieve additional $CO_2$ reductions is a cost effective measure to achieve defined climate protection targets.

## 5. Possibilities for heat retention in industrial installations

About 50 % of the total $CO_2$ emissions are caused by industry. An effective heat retention and thereby an effective energy saving in the industry contributes substantially to the husbanding of resources and to the aim to reduce $CO_2$ emissions. A future-oriented dimensioning of insulation layer thicknesses at industrial installations is, therefore, of specific importance.

VDI 2055 [5] declares in chapter 6.1.1 "Dimensioning criteria":

Basis for the determination of insulation layer thicknesses are operational and economic requirements as well as legal obligations and environment protection directives, e. g. the German energy savings directive – EnEV

## 6. The economic insulation layer thickness on industrial installations

Together with operational aspects, the economic insulation layer thickness is frequently used to determine the capacities of insulation systems as a criterion. It is defined according to VDI 2055 as that insulation layer thickness, where the sum total of the investment expenditure for the insulation and the despite insulation remaining heat loss costs is a minimum when considering the expected lifecycle.

It depends predominantly on the following parameters:

- Diameter of the object to be insulated
- Medium temperature
- Thermal conductivity of the insulation material
- Investment expenditure and the financing mode
- Annual operation time
- Heat price and its variations over time

The heat price is composed of:

- Fuel cost
- Operational and maintenance costs
- Capital service for the installation

Examples are given in Table 6.

| *Power plant* | *Fuel costs* | *Operation and maintenance costs* | *Capital service* |
|---|---|---|---|
| *Hardcoal* | 41 % | 27 % | 32 % |
| *Gas a. Steam* | 76 % | 12 % | 12 % |

*Table 6: Cost percentages of the heat price [6]*

The cost percentages mentioned above are varying strongly in different branches of industry. The investigations in chapter 1 are conducted with the specimen heat prices of 6 €/GJ and of 10 €/GJ.

It must be remembered, however, that an increase in energy expenditure can be forecast for the next years and decades with great certainty. Even if the energy expenditure development should continue in a less erratic fashion than in the last decade (150 % increases), one can with certainty assume that energy expenditure will continue to grow.

Whilst in the past, the energy expenditure increase has frequently been disregarded when determining the economic insulation layer thickness sW, this cannot be accepted today. Figure 3 shows the sW dependence of the annual energy expenditure increase for service periods n = 5 a, n = 10 a and n = 20 a.

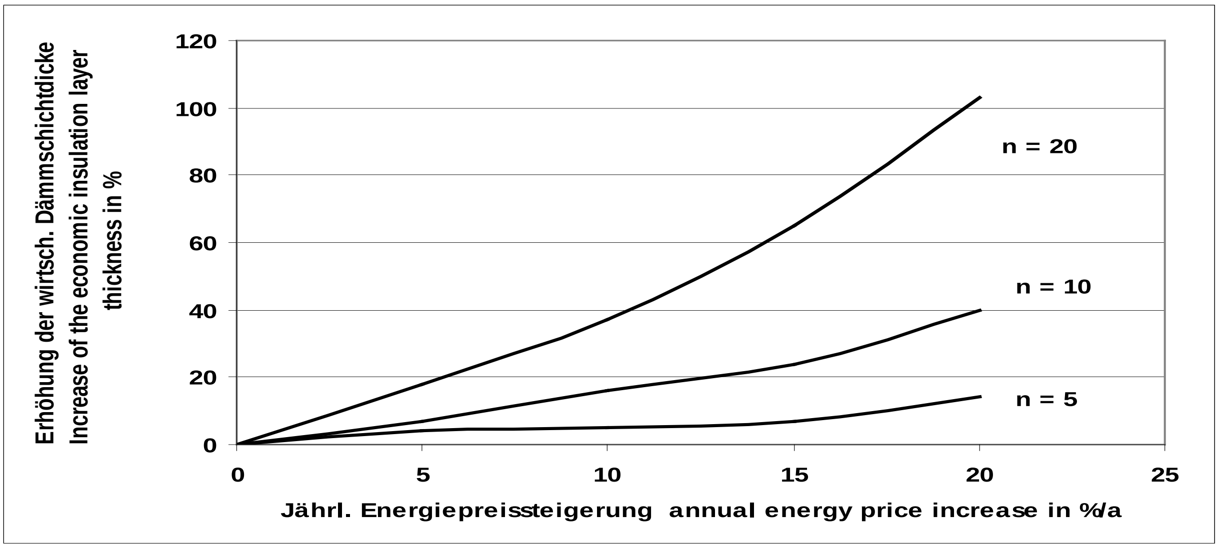


Figure 3: Increase in percentage of the economic insulation layer thickness dependent upon the annual energy expenditure increase for **W = 10 € / GJ** ; **$T_{med}$ = 300 °C and DN 150**

## 7. Increase of insulation layer thickness

For reasons of sustainability – regarding both a continued profitability in the face of increasing energy expenditure as well as the climate protection – the insulation layer thickness must be increased over the technically or economically advised dimension.

The influence of increased insulation layer thicknesses on the expenditure and the profitability of industrial insulations will therefore be investigated below [7].

Considerations start at the economic insulation layer thickness according to VDI 2055 and use the assumption that the heat loss shall be lowered by 25 % compared to the heat loss associated with the economic insulation layer thickness.

The resulting increased insulation layer thickness s* is termed the "ecological" or "environment protecting" insulation layer thickness.

Figure 4 shows the connection between the heat loss costs and the insulation layer thickness.

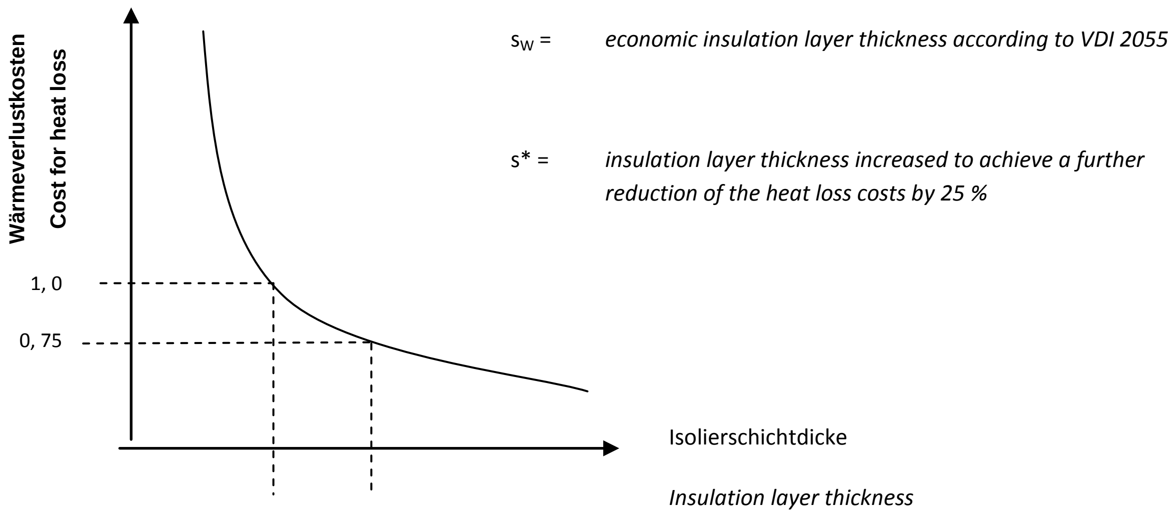


***Figure 4: Relationship between the costs of heat loss and the insulation layer thickness***

In Figure 5, examples of three pipes with the nominal diameters DN 50, DN 150 and DN 500 are considered at different medium temperatures. On the basis of currently common economic insulation layer thicknesses, the percentage increases shown for the insulation layer thickness result, if a 25 % heat loss reduction is the aim.

Within the framework of its energy and climate protection programme, the German federal government even envisages until 2020 a 40 % reduction of CO2 emissions compared to the starting point 1990.

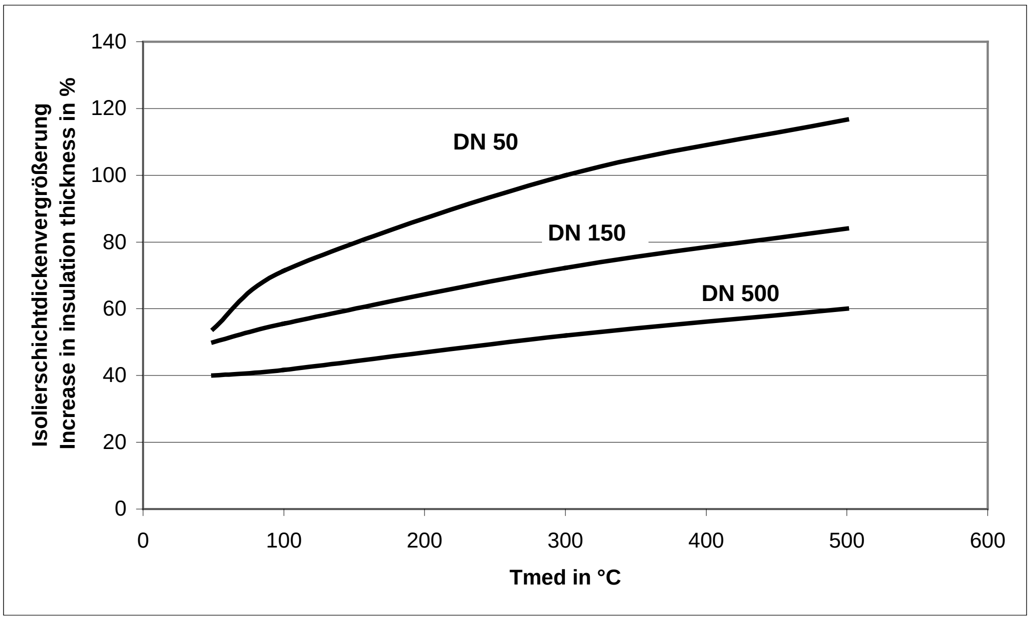


***Figure 5: Insulation layer thickness increase in percentage to achieve a 25 % heat loss reduction***

Explanation:

To achieve an additional reduction of the heat loss by the assumed 25 %, an insulation layer thickness increase by 55 % is required at a medium temperature □M = 100 °C and a diameter DN 150.

The increases of insulation layer thicknesses vary dependent upon the diameter and the medium temperature between 40 % and 120 %, where at low diameters the curvature effect and the surface increase with increasing insulation layer thickness have a specifically notable influence.

The increase of insulation layer thicknesses needed for a further 25 % reduction of heat loss is considerable, and to question the associated cost increases is entirely justified.

The expenditure is considered in more detail below, however, only regarding the actual insulation expenditure without costs associated with installations and buildings.

## 8. Economic and ecological insulation layer thickness

The connection between economic and ecological insulation layer thicknesses and the related expenditure is demonstrated in Figure 6.

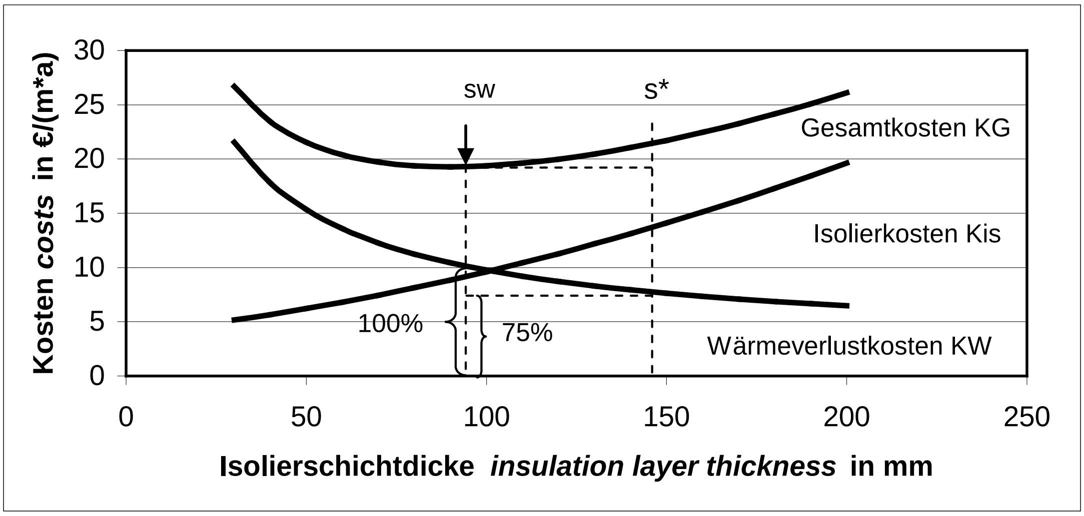


***Figure 6: Economic insulation layer thickness and costs for an additional 25 % reduction of heat loss***

Figure 6 shows the development of heat loss costs (KW), insulation investment costs (Kis) and total costs (KG). The heat loss costs which remain at the minimum of the total cost curve, i. e. the economic insulation layer thickness are set to 100 %. As the aim is to lower them to 75 % of the value remaining at the economic optimum, the heat loss must be reduced by further 25 %.

The cost curve shown in Figure 6 demonstrates that the curve of the total costs is very flat in the area of the total cost minimum. This means that the total costs, despite an increase of the insulation expenditure, do only moderately increase, since the heat loss savings are still very much accentuated in this area.

## 9. Peculiarities at price jumps

Price jumps, occurring e. g. in mineral wool insulates at the transgression to an additional insulation layer, have been disregarded. If price jumps occur in the expenditure function, it may be required in specific cases to conduct a special calculation, or to limit the insulation layer thickness increase to values lying directly in front of the price jump.

## 10. Densities of heat flow rate

Frequently, a set density of heat flow rate is used as a criterion for the dimensioning of insulation systems.

In AGI working document Q 101 "Insulation work in power plant components" a density of heat flow rate of 150 W/m2 has been recommended. In buildings, when the heat released by the insulation system is partly led back into the boiler system over a combustion-air blower, 200 W/m2 are considered sufficient.

The current edition of Q 101 dates back to the year 2000. As is shown in Figure 1, primary energy prices have risen considerably since, so that a reduction of the value of 150 W/m2 makes sense. Table 7 provides decision assistance. In this table, s150 mean the insulation layer thickness for a density of heat flow rate of 150 W/m2, sw is the economic insulation layer thickness for a heat price of  and s* the ecological insulation layer thickness.

| DN | $\vartheta_M$ °C | $s_{200}$ mm | $s_{150}$ mm | $s_{100}$ mm | $s_W$ mm | s* mm |
|---|---|---|---|---|---|---|
| 50 | 300 | 50 | 60 | 80 | 100 | 190 |
| | 500 | 100 | 120 | 160 | 150 | 320 |
| 150 | 300 | 60 | 70 | 100 | 140 | 230 |
| | 500 | 120 | 150 | 210 | 200 | 350 |
| 500 | 300 | 60 | 90 | 120 | 200 | 300 |
| | 500 | 140 | 190 | 260 | 290 | 450 |

***Table 7: Insulation layer thicknesses for different requirements***

Table 7 shows that the common recommendation of an acceptable density of heat flow rate of 150 W/m2 can, already for economic reasons, not are maintained.

## 11. Summary

A consideration of pay-back periods shows that the reduction of heat losses through insulations is a cost-effective and economic measure to save energy. The pay-back period PBP* even increases only insignificantly where the insulation layer thickness is increased over and above the economic up to the ecological measure: environment protection through insulation is thus very cost-effective.

Already a low additional effort can constitute a significant contribution to CO2 reduction!

## Literature


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This FESI document is based on a Technical Letter of BFA WKSB (German Insulation Association) No 6 High profitability with environment protecting insulation layer thicknesses. It provides a general discussion of the technical issues mentioned therein. It does not replace detailed calculations and assessments of prevailing physical conditions in complicated building tasks.

## 12. Further information

More detailed information or advice can be obtained from the insulation contracting industry association in your country via the FESI website www.fesi.eu .