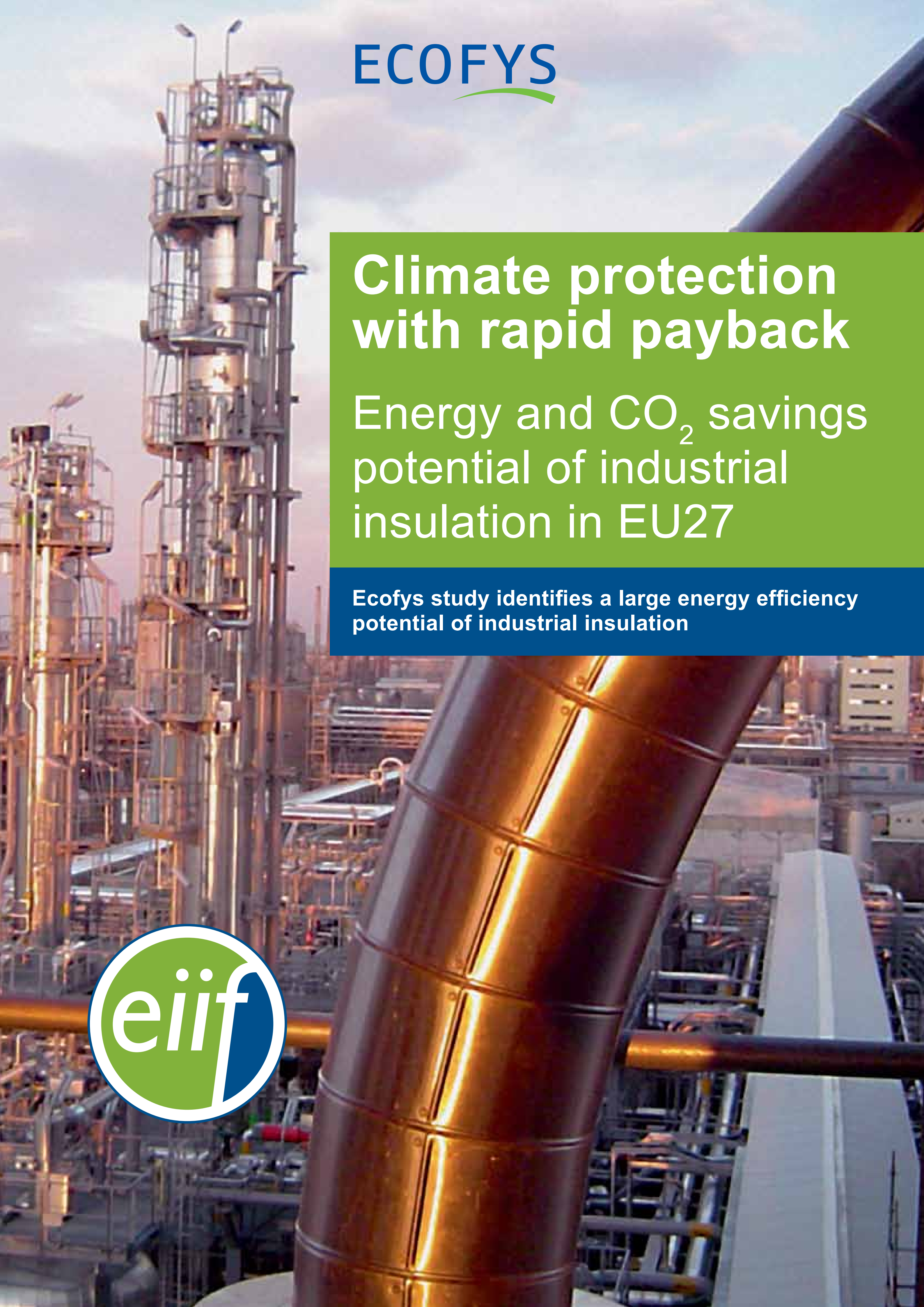

ECOFYS

Climate protection with rapid payback

Energy and CO_2 savings potential of industrial insulation in EU27

Ecofys study identifies a large energy efficiency potential of industrial insulation

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Climate protection with rapid payback

Energy and emissions savings potential of industrial insulation in EU27

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By order of: European Industrial Insulation Foundation

Date: 19 June 2012

Executive summary

Background of the study

Current practice in industry is reported to lead to levels of insulation that are less than those which would be cost-effective under current market conditions. This can result from the use of design criteria based only on maximum safe surface temperature or based on generic heat loss rates without consideration of the cost effective level.

It is also observed that in many cases thermal insulation in industry is poorly maintained and parts remain uninsulated creating thermal bridges resulting in excessive heat losses. Poor insulation not only leads to increased cost for energy and unnecessary emissions but also to higher thermal stresses, which can accelerate wear and leading to more frequent breakdowns. Other effects of poor insulation include reduced product quality and increased costs of maintenance. In many cases, the loss of energy to work spaces that are climate controlled creates additional burdens on cooling systems.

The industrial insulation industry is therefore convinced that there is a significant energy saving and emissions mitigation potential related to improved thermal insulation in EU27 industry. This potential is currently untapped despite being cost-effective to implement and offering the additional benefits mentioned above. Against this background, the European Industrial Insulation Foundation (EiiF) commissioned Ecofys to study this potential.

Research questions and approach

This study aims to answer the following four questions:

1) What is the energy savings and CO_2 emissions mitigation potential resulting from insulating currently uninsulated parts and from better maintenance of insulation systems?

2) What is the energy savings and CO_2 mitigation potential from improving current insulation to cost-effective levels? Cost-effective insulation in this study is defined as the insulation that minimises the sum of the costs of heat loss and the costs of insulation.

3) What is the energy savings and CO_2 mitigation potential from improving current insulation beyond cost-effective levels to even more energy-efficient levels? Energy-efficient insulation in this study is defined as the insulation at which the sum of the costs of heat loss and the annualised insulation investments are equal to the costs of typical current insulation while offering an additional energy savings and CO_2 mitigation potential.

4) How can these potentials best be realised?

This study investigates savings potentials from improved insulation in EU industry and the power sector under realistic market conditions. Nuclear power plants and power production by renewable sources were left outside the scope of this study as well as insulations of cold applications.

Case studies of insulation projects have been used to compare energy loss and investments related to different levels of insulation. The analysis was performed for three temperature levels: <100 °C; 100 – 300 °C and >300 °C. Results at the level of the case studies were extrapolated to European level using data on current energy use. Other assumptions have been made where needed on the basis of literature and expert[1] input. All potentials are based on a 9% discount rate, an average insulation lifetime of 15 years and a 2-3% per year increase of the price of energy net of inflation.

Energy savings and CO_2 emissions mitigation potentials

The saving potentials are shown in the figure and table below. A savings potential was found to exist across all regions, sectors and equipment and operating temperatures. Potentials vary between regions and sectors, due to differences in energy use, temperature profiles and fuel mix. About two thirds of the energy and emission savings potential is in uninsulated or damaged insulation. The remaining part of the potential would come from improving insulation on currently insulated surfaces.

The results show that insulating all surfaces to cost-effective levels would avoid approximately 66% of current heat loss. This corresponds to about 620 PJ (~480 PJ for industry and ~140 PJ for fossil fuel-fired power plants). Improving insulation to energy-efficient levels would even avoid approximately 75% of current heat loss. This corresponds to about 710 PJ (~550 PJ for industry and ~160 PJ for fossil fuel-fired power plants). These saving potentials represent about 5% of industrial energy consumption and about 1% of energy **input** to fossil fuel-fired power plants[2].

Table Total annual savings potential of improving thermal insulation up to cost-effective or energy efficient levels in EU27

	Annual cost - effective savings potential	Annual energy - efficient savings potential
Energy savings potential	620 PJ	710 PJ
CO_2 emissions reduction potential	49 Mt CO_2	56 Mt CO_2
Reduction of heat loss over surfaces	-66%	-75%

[1] The group of experts that provided input to this study represented different insulation companies and most of them are certified TIPCHECK engineers trained by EiiF in insulation energy appraisals (TIPCHECK = Technical Insulation Performance Check). All experts within the group have extensive experience with insulation projects and throughout their careers held different positions in the insulation industry.

[2] Even though the energy savings potential for the power sector is substantial in absolute terms, compared to the savings potential for industry, it is relatively low as share of total input. The reason for this is the nature of the power generation which is an energy conversion process.

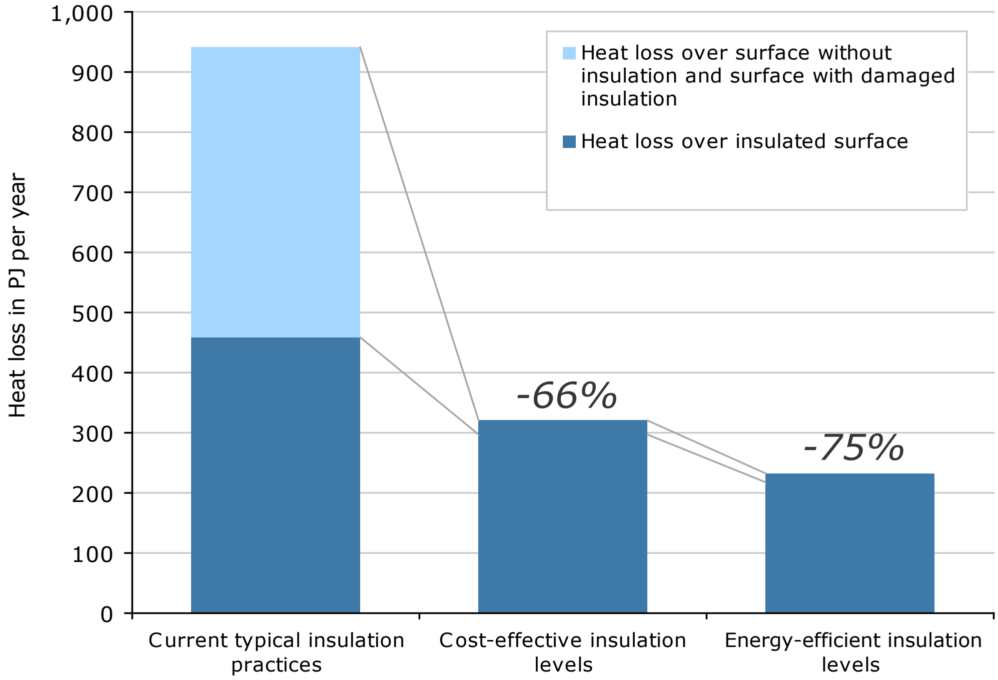

Figure Potential from improving current insulation and insulating surfaces without or with damaged insulation; Reductions in heat loss assume insulation of the total surface of all equipment. In reality, a small share of the total surface cannot be insulated due to technical restrictions.

How big is the potential?

The annual cost-effective potential is more than:

- The annual energy consumption of 10 million households
- The annual energy input to 15 coal-fired power plants with a production capacity of 500 MW
- The annual industrial energy consumption of the Netherlands.
- The annual CO_2 emissions of 18 million middle class cars each running 12,500 kilometres per year.
- The order of magnitude of the total savings potential from technical insulation (~5% of industrial energy consumption and ~1% of energy input to fossil fuel-fired power plants) shows that improving insulation can significantly contribute to achieving EU's 2020 climate and energy targets, known as the "20-20-20" targets:
  - A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.
  - A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
  - 20% of EU energy consumption to come from renewable resources

Investments in energy efficient insulations pay back

Improving insulation will not only save energy but also reduce costs. The figure below shows the total costs of two different insulation solutions over a 15-year lifetime. The costs of the current typical insulation solution (usually fulfilling process or safety requirements only) are taken as reference.

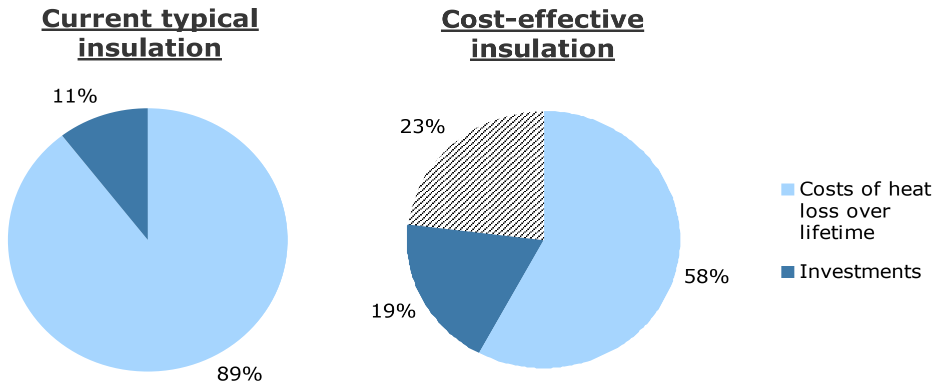

Figure Visualisation of cost savings from reduced heat loss due to the use of cost-effective insulation

The figure shows that although cost-effective insulation requires a higher initial investment, because of cost savings from reduced energy loss, it will lead to lower costs over the total insulation lifetime.

Costs for current typical insulation:

11% investment in insulation + 89% costs for energy due to heat loss = 100%

Costs for cost-effective insulation:

19% investment in insulation + 58% costs for energy due to heat loss = 77%

The cost-savings that can be achieved depend on characteristics of the specific application. As a general rule, the achievable cost savings of improved insulation increase with longer operation times and lifetimes.

Cost-effective or energy efficient industrial insulation will generate jobs

Apart from saving energy and costs, implementing cost-effective technical insulation on all surfaces could save jobs and even increase employment by, roughly estimated, 4,000 people EU-wide. All results were found to be consistent with expert opinions and figures found in literature.

How to tap the potential?

1) **Insulate uninsulated and damaged parts**

This study shows that insulating uninsulated equipment and repairing damaged insulation parts combines the biggest energy and emission cost-effective saving potential with payback periods of less than one year. It is therefore recommended that industry focuses first on those uninsulated and damaged parts which can be insulated quickly and easily and bring immediate benefits.

2) **Evaluate cost-effectiveness and consider insulating today beyond today's cost-effective levels to be prepared for likely increasing costs for energy and CO_2 emissions**

Most plants have an insulation system that meets safety rules and process needs or that leads to a generic maximum heat loss rate. Such insulation systems typically have a lower performance than what would be cost-effective. Compared to current practices, cost-effective insulation will therefore in general save both heat and money. This study therefore recommends evaluating cost-effectiveness in future insulation projects. Since insulating now saves money in the future, the cost-effectiveness should be evaluated using expected future costs of energy. Removal and replacement of current insulation is only attractive under some circumstances. Replacing damaged insulation or insulating bare equipment is normally always cost-effective. The savings potential of improving current insulation to cost-effective levels is therefore best realised during general overhauls and installation of new equipment when new insulation needs to be applied anyway.

Insulating beyond cost-effective levels is a way to partly mitigate the risk of increasing energy prices and can help achieve company goals for energy efficiency and for greenhouse gas emissions reduction. This study investigated the level of energy efficient insulation. This term stands for insulation beyond the cost-effective level at which the sum of the costs of heat loss and the annualised insulation investments are equal to the costs of typical current insulation. The level of energy efficient insulation reduces heat loss sustainably at no additional overall costs but requires higher initial investments than typical insulation.

According to experts, the present absence of cost-effective insulation is partly the result of organisational barriers. To realise the potential of improved insulation, it is therefore recommended that these barriers are identified and tackled where they exist.

3) **Involve insulation experts early in the planning of new build and turnaround projects to ensure thermal efficient and cost-effective insulation systems:**

Application of insulation material is quite often hampered by limitations in the space available, for example between pipes with different temperatures. Although this can (partly) be solved by using insulation materials with better insulating properties these would typically be more expensive. This drawback can be minimised or even avoided by involving insulation engineers early enough during the design phase of new equipment or retrofit projects.

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1 *Introduction*

1.1 Framework and goal of this study

In 2007, EU leaders endorsed a set of ambitious climate and energy targets to be met by the year 2020. These EU ambitions are known as the 20-20-20 targets:

- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.
- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources

In this policy context, there is significant attention on measures that reduce energy demand and mitigate CO_2 emissions in all sectors of the economy such as the built environment, transport and industry.

From their experience, the European industrial insulation Foundation (EiiF) is convinced that there is a significant energy saving and CO_2 mitigation potential related to improved thermal insulation in industry and that this potential is currently untapped despite being cost-effective to implement. With energy and CO_2 prices likely to rise, this potential is probably growing. Against this background, EiiF commissioned Ecofys to answer the following three questions:

1) What is the energy savings and CO_2 mitigation potential resulting from better maintenance of insulation systems and from insulating currently uninsulated parts?

2) What is the energy savings and CO_2 mitigation potential resulting from cost-effective thermal insulation in the power sector and industry?

3) What is the technical potential available beyond current cost-effective insulation?

The potentials assessed in this study would on average be profitable under real market conditions for industrial sectors and fossil-fuel power generation. Together these sectors constitute around 35% of Europe's primary energy use (based IEA, 2010). Fossil-fuel fired power generation covers both electricity only and combined heat and power (CHP) plants. These plants account for 56% of total power generation in EU 27. The remainder is generated by nuclear power plants (28%) and renewable sources (16%). Neither of these last two is covered by this study as they do not give rise to greenhouse gas emissions.

Insulations of cold applications also fall outside the scope of this study as the majority of industrial processes take place in hot applications (in industry cold insulations have a market share of about 5%). Furthermore the effects of inadequate cold insulation are better detectable (condensation formation most often followed by ice building) so that e.g. uninsulated parts in cold processes are less to be found. Nevertheless, wherever and whenever cold systems are not insulated properly: insulation is e.g. insufficiently dimensioned, damaged or not maintained consequently; they cause, besides large energy losses, also immediate condensation problems. (For more information, please see info box about special requirements for cold applications in chapter 1.4).

1.2 Why insulate?

In both the power sector and industry, fuel is burned to generate heat (in furnaces, steam boilers etc.) that is used in a variety of process units. The larger the share of heat that is used productively, the higher the efficiency of a process. To reduce heat loss, thermal insulation is therefore applied to boilers and ovens, pipes, tanks and vessels and other equipment. This allows an efficiency gain that reduces the energy use per unit of output and of the associated greenhouse gas emissions and those of other pollutants such as CO, NO_x and SO_x.

In many cases, insulation also plays an important role in providing functions such as personal protection, process control, product stabilisation, freeze protection, noise control and fire protection (Barnett, 2003). Poor insulation not only leads to increased costs for energy, but also to higher thermal stresses, which can accelerate wear and subsequently lead to more frequent breakdowns. Other effects of poor insulation can include reduced product quality, increased costs of maintenance (U.S. DOE, 2007) and additional burdens on air conditioning, wherever excess heat is lost to work spaces (U.S. DOE, 2007).

1.3 Why is the potential still there?

Industrial insulation experts[1] observe that in many cases, thermal insulation in industry is poorly maintained and that some parts remain uninsulated creating thermal bridges resulting in excessive heat losses. They also note that the level of insulation applied is typically based on requirements regarding the maximum surface temperature that equipment is allowed to reach to avoid personal injuries or based on generic maximum heat loss rates allowed. It is very rare that industrial companies require that the insulation system is designed based on criteria of cost-effectiveness over the lifetime of the insulated piece of equipment. In the past, when fuel prices were lower this would in many cases not have led to a large difference. Nowadays, the price of energy is higher and is expected to grow even further. As a result there is an increasing gap between current and cost-effective insulation levels. Additional costs for CO_2 emission allowances will accelerate this trend.

According to expert experiences, there are usually several reasons for companies not to make detailed assessments of the cost-effectiveness of insulation and not to maintain existing insulation:

There may be a general lack of information for the main decision makers about the large energy savings potential of industrial insulation

- Insulation is a relatively small part of investments. Even though poor insulation leads to higher costs of heat loss over many years, it is often seen as less important.
- Retrofitting insulation can, or can be perceived to, cause disruption in production.
- In common with other energy efficiency measures, it is not the core business of the main decision makers.

[1] The group of experts that provided input to this study represented different insulation companies and most of them are certified TIPCHECK engineers trained by EiiF in insulation energy appraisals (TIPCHECK = Technical Insulation Performance Check). All experts within the group have extensive experience with insulation projects and throughout their careers held different positions in the insulation industry.

- There may be a lack of information about improvements in insulation materials and in the design of modern insulation systems
- Split or unclear responsibility for decisions on maintenance.

1.4 Approach

The total costs of insulation are the sum of annualised investments and the annual costs of heat loss. As the degree of insulation increases, the investment costs increase and the cost of the heat loss decrease. As schematically shown in Figure 1 - 1, a minimum exists (point B) where total costs are lowest[1]. Throughout this report, this level is referred to as the **cost-effective level of insulation.**

Figure 1 - 1 shows that further potential exists beyond cost-effective insulation levels. Beyond cost-effective level, heat loss is reduced even further at little additional cost. A point (point C) can be defined where the total costs per year are equal to the costs of current insulation but where insulation quality is significantly better. Throughout this report, this level is referred to as the **energy-efficient level of insulation.**

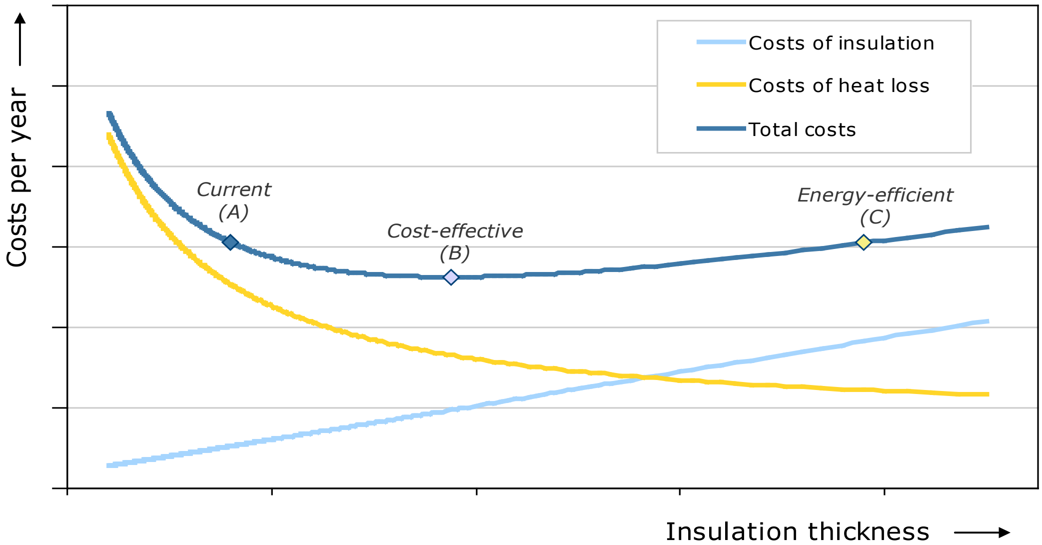

Figure 1-1 Cost curve of insulation of a flat surface

The best insulation solution varies from application to application depending on many design factors such as for example the shape and temperature of the surface that is insulated, sensitivity to corrosion or the need for fire-proof materials. However, the main driver of differences in heat loss rates is the difference in temperature between a surface and its surroundings. As it would be impossible to account for all different aspects in a study such as this, this study concentrates on an analysis for three temperature levels for each sector:

- Low-temperature (ambient temperature – 100 °C)[2]
- Middle-temperature (100 – 300 °C)
- High-temperature (>300 °C)

[1] At this point the Net Present Value of the project is highest.

[2] This study does not focus on cold insulation where the temperature of equipment is lower than ambient temperature; see Box 1)

Figure 1 - 2 gives a schematic overview of the data sources used. Relations between investments in insulation (Euro), the ratio between heat loss to current heat loss (-) and the rate of heat loss (W/m^2)[1] have been obtained from case studies: a coal-fired power plant for high-temperature surfaces, part of a chemical plant for middle-temperature surfaces and part of a brewery for low-temperature surfaces. More background on the case studies used in this study is provided by Box 2.

The fuel mix for each sector was obtained from energy statistics (IEA, 2009). Current and future fuel prices were based on a forecasting study of the European Commission (EC, 2009b). This study accounts for the effect of climate change policies by assuming costs of 15 Euro/tCO_2. Prices of energy are assumed to increase by 2-3% per year net of inflation.

Heat loss, investments and savings have been extrapolated to European level using data on current energy use from energy statistics and assumptions for current insulation levels and heat loss on the basis of literature and expert judgements. IPCC emission factors have been used to express savings in terms of greenhouse gas emissions reduction. All potentials are based on a 9% discount rate and an average insulation lifetime of 15 years.

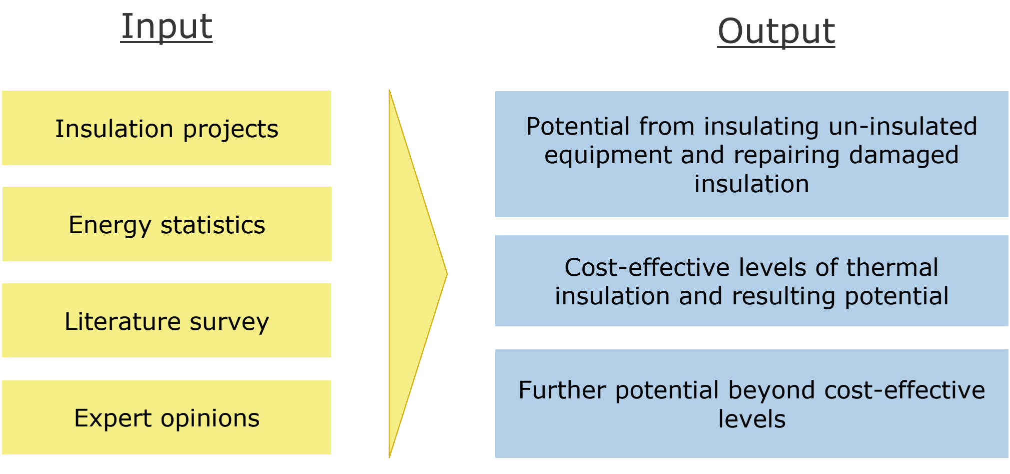

Figure 1-2 Overview of data sources and study results

Overall, results are based on the best data available to the authors at the time that the study was performed. Not enough data about insulation projects was available to allow robust statistical analyses. This study therefore relies on expert assumptions and secondary data from a variety of sources.

[1] The relation between heat loss (TJ /year) and rate of heat loss (W/m^2) is not straightforward since the rate of heat loss (W/m^2) has area in the denominator and for non-plane surfaces such as cylinders (pipes), spheres etc., the surface area increases with increasing insulation thickness.

Box 1 Special requirements for cold applications (temperatures below ambient temperature) (EiiF, 2012)

The FESI Technical Lexicon defines “Cold insulation” as follows: “Assembly of components which reduces heat gain of the cold medium.” In principle, experts talk of “cold insulation” wherever the medium temperature is below the temperature of the ambient air. The temperature range of “cold insulation” is therefore between -273 °C and ambient temperature. Insulations of cold applications fall outside the scope of this study because of their modest market share (~5%) and due to their special requirements. This does not mean that there is no energy savings potential in the “cold” temperature range below ambient temperature:

The main duty of all insulation systems, and therefore also of cold insulation is the reduction of heat flow rates. With hot insulation, the heat flow rate is from the object towards the ambient air, with cold insulations it is the other way around: from the ambient air to the object. Compared with hot insulation systems cold insulation systems have however more and further requirements to fulfil than limiting heat loss or respectively heat gain: cold insulations always need to avoid the danger of moisture entering the insulation material. This moisture results from condensation of water vapour out of the ambient air, whenever the temperature at the object or inside the insulation material is below the dew point. Water vapour will be transported into the insulation by differences in the overall pressure (air movement) and through differences in the partial water vapour pressure (water vapour diffusion) between the ambient air and the object to be insulated. Therefore it is first of all the minimisation of moisture in the insulation which determines the design of a cold insulation system. If this danger is not prevented, immediately water and/or ice form at those parts of the insulation system where the temperature is below the dew-point temperature or the freezing point of water. Whereas the heat “just escapes” from poorly or not insulated hot insulation systems the consequences of ineffective cold insulation systems (below dew-point temperatures) cause, besides great energy losses, immediately negative effects on the industrial process:

- In the insulation material, they reduce the insulating effect considerably. The thermal conductivity of water is 20 times that of air, the thermal conductivity of ice is 100 times that of air. Extensive heat gain of the cold medium is the consequence.
- Water can cause corrosion on insulated installations and on the inner surface of the cladding which could lead to material failure and cause severe accidents like bursting pipes.
- Water and ice increase the weight of the insulated system. Cold piping can collapse under this additional load.

Cold insulations have, in general, a limited life expectancy: They are unstable systems, which for physical reasons react sensitively to damages. They must be maintained regularly, which includes a routine check of sealings and interruptions. This is needed not only to save decent volumes of energy but also to keep industrial processes running.

Box 2 Case studies

This study uses, amongst others, the data from five insulation projects. For each of these projects, the investments (Euro), heat loss (TJ/year) and insulation thickness (mm) was available for a wide range of heat loss rates (W/m^2). Consistent data for the price of insulation material and installation were used for all projects. Trends observed from the projects in heat loss, heat loss rate and insulation thickness are the result of laws of physics and will be valid for typical cases observed in practice. Exact quantitative relations will however vary from application to application. The relations found for the used case studies are by insulation experts believed to be within the range of what is typically observed and not to represent extremes. To allow for comparison, all case studies were normalised with respect to annual operation time (90% utilization rate) and surface area:

- 1 GW coal-fired power plant: this case study predominantly involves temperatures between 300 °C and 500 °C although the complete power plant has been considered including all piping, vessels, channels and plane surfaces, an e-precipitator and a flue gas desulphurisation plant.
- Part of a chemical plant: the project involved a set of pipes with an average temperature of approximately 200 °C
- Part of a methane compressor station with a throughput of 55,000 Nm^3/h and a pressure increase from 35 to 200 bar; the project involved a set of pipes with a total length of approximately 200 m and an average temperature of 150 °C.
- Part of a brewery with a capacity of 3,500,000 hl; the project involved the insulation of two lauter tuns (vessel used in the brewing process to separate out wort) and related pipelines with a temperature of 84 °C.
- Part of an atmospheric distillation unit at a refinery. The unit has a capacity of 143,396 barrels/day and a maximum thermal input rate of 130 MW. The insulation project involved approximately 1,100 m^2 of the tower wall. The surrounding equipment (furnace, heat exchangers, pipelines, other small surrounding towers) consists of around 40,000 m^2 of already insulated surface.

1.5 Outline of this report

The structure of this report is as follows:

- Chapter 2 discusses the project approach and assumptions.
- Chapter 3 shows the energy savings and CO_2 emissions mitigation potentials from improved insulation. The breakdown of these potential by sector and region is shown in Appendix A. Appendix B describes a number of examples of insulation projects. The potentials were tested on their sensitivity to a number of key assumptions. The results of this sensitivity analysis are shown in Appendix C.
- Chapter 4 discusses the investments required and the effects on employment.
- Finally, chapter 7 gives the main conclusions and recommendations

2 *Inputs to calculations*

The general approach to determine savings potentials is described in the introduction. This chapter describes how the inputs to that approach were obtained: current insulation (section 2.1), current heat loss (section 2.2) and the relation between the rate of heat loss per square meter on the one hand and investments in insulation (section 2.3) and total heat loss (section 2.4) on the other hand.

2.1 Current insulation

The company which uses insulation typically defines to what level its equipment is insulated. According to industry experts, most plants are operated with an insulation system specified to meet safety rules, process needs or a generic maximum heat loss rate. Specifications asking for an economic insulation system are an exception (EiiF, 2010a; EiiF, 2010b, EiiF, 2010c)

Insulation performance is usually specified as a typical heat loss rate per unit of surface area (W/m^2) insulated. A lower heat loss rate corresponds to a higher degree of insulation. A current heat loss rate of 150 W/m^2 can be inferred from a study to technical information from KAEFER (KAEFER, 2010), expert input (EiiF, 2010b), standards specifications of six companies (four in the power sector, one in the brewery sector and a provider of boiler systems) (EiiF, 2010c). This value is used for high- and middle-temperature applications. As heat losses are driven by temperature differences, low-temperature surfaces typically have lower rates of heat loss. In this study a heat loss rate of 100 W/m^2 for low-temperature applications is assumed. Sectors and regions have different temperature profiles and the distinction of heat loss rates by temperature levels also leads to differences in the average heat loss rate between sectors and regions.

In reality, the average heat loss at a given temperature level varies from sector to sector and from region to region. It was not possible within the scope of this study to account for such variations as even within sectors there are significant differences in insulation performance (EiiF, 2010a; EiiF, 2010b).

The heat loss rates discussed above refer to insulated surfaces. Not all surfaces are however insulated. The company website of Hertel (2011), a global company, states that in a typical plant 10-19% of insulation is damaged or missing. For U.S. industry, King (2010) estimates that 10-30% of all exposed mechanical insulation becomes damaged or missing within 1 to 3 years of installation. Lettich (2003) presents two typical case studies of U.S. plants, a chemical plant and a refinery, in which about 20% of all insulation is damaged. For the EU, where insulation performance is typically better, NCTI estimates that on average 5-10% of all surfaces is badly insulated (EiiF, 2011). Based on the information above and additional expert judgements, the share of equipment without insulation or with damaged insulation is conservatively estimated to be 10%, 6% and 2% for low-, middle- and high-temperature surfaces respectively.

The heat loss over surfaces without or with damaged insulation is predominantly dependent on surface temperature and the remaining degree of insulation (for damaged insulation). Estimates are made based on calculations of heat loss rates in accordance with guidelines from the Association of German Engineers (VDI, 2008). As a general rule, the heat loss from a hot, bare surface can be as much as 20 times greater than from a surface insulated to current industry standards (Hart, 2003). Calculations by experts show that for high-temperature surfaces, heat loss rates can be even higher depending on the temperature.

Table 2 - 1 provides an overview of assumptions with respect to the status of current insulation.

Table 2-1 Assumptions for current rates of heat loss at different temperature levels, based on expert input (EiiF, 2010b, 2010c; KAEFER, 2010); heat loss rate over poorly or uninsulated surfaces (based on calculations); share of equipment that is currently not insulated (Hertel, 2011; Lettich, 2003; King, 2010 and additional expert judgements)

Type of application	Average current rate of heat loss over insulated surfaces in W/m^2	Average rate of heat loss over surfaces without or with damaged insulation in W/m^2	Average share of equipment without or with damaged insulation
Low-temperature applications (<100 °C)	100	1,000	10%
Middle-temperature applications (100 - 300 °C)	150	3,000	6%
High-temperature applications (>300 °C)	150	10,000	2%

2.2 Current heat loss

To calculate the current heat loss, the fuel input to each sector is first related to the different temperature levels (section 2.2.1). In a second step, a percentage of that fuel input is assumed to be lost over insulated surfaces (section 2.2.2).

2.2.1 Fuel-use related to each temperature-level

Figure 2 - 1 shows the 2007 fuel consumption of refineries and manufacturing industry, 10,673 PJ in total. In addition to this fossil fuel-fired power generation used 17,004 PJ.

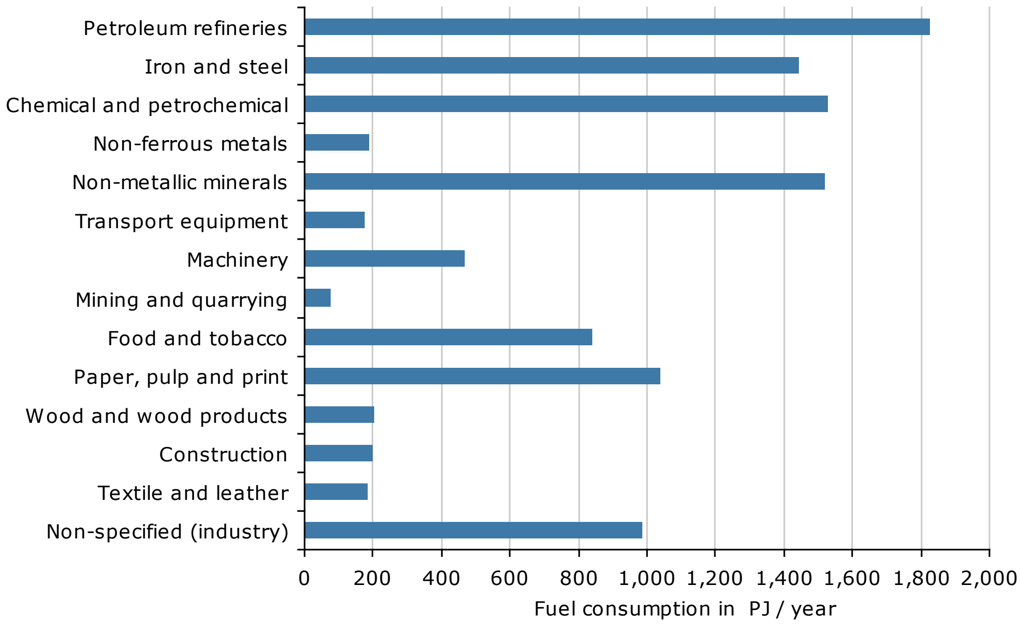

Figure 2-1 2007 fuel consumption by refineries and manufacturing industry (IEA energy statistics); The depicted fuel consumption is net of any fuel used in conversion processes from one energy carrier to another (e.g. crude oil to petroleum products in refineries, coal to cokes and cokes to blast furnace gas in the iron and steel industry).

For each sector considered, the fuel use is distributed over low-, middle- and high-temperature applications in terms of shares of surface area (see Figure 2 - 2) (based on ECN (2002), FfE (2007), FfE (2009) and EC (2009)). This distribution takes into account that due to cascading of energy use, high-temperature processes (e.g. power generation) also involve low temperature surfaces. The figure shows that some sectors predominately involve high-temperature surfaces whereas others predominately involve only low-temperature surfaces.

The fuel inputs from Figure 2 - 1 were combined with the temperature profiles from Figure 2 - 2 to obtain the fuel input for each sector associated with each temperature level.

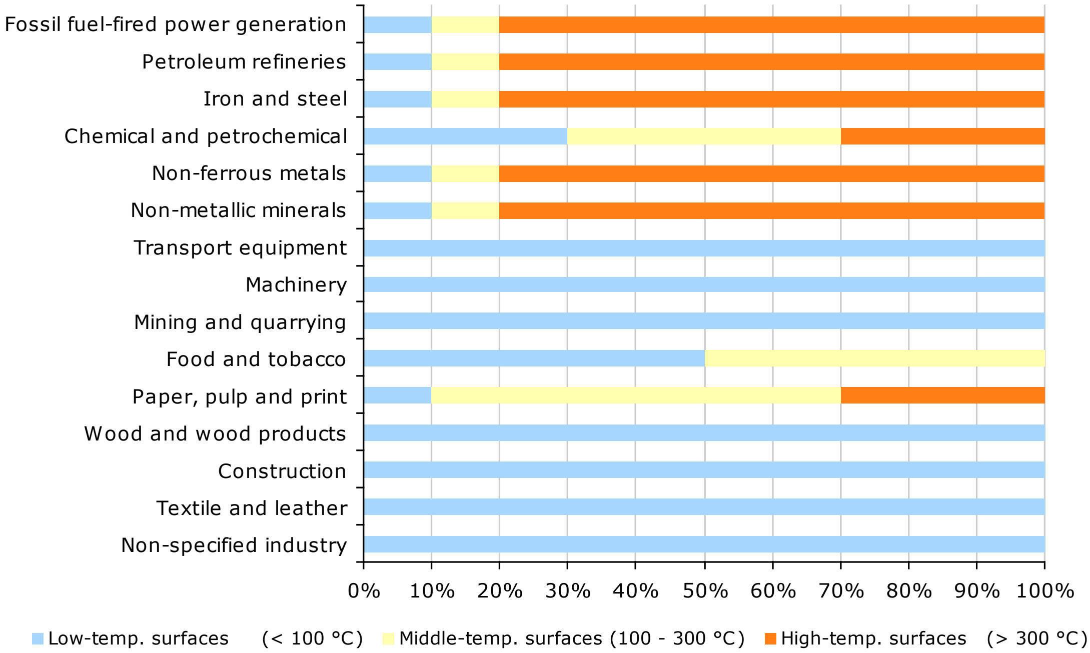

Figure 2-2 Distribution of fuel input over surfaces with different temperature levels in various industrial sectors based on ECN (2002), FfE (2007), FfE (2009) and EC (2009)

2.2.2 Energy loss over surfaces

The amount of heat that is lost over surfaces normally only represents a small fraction of the energy input to a process. A share of energy input is converted into useable work driving the conversion of raw materials or intermediates into final products. Energy that is not converted to useable work or services can be considered to be lost. Not all losses take place due to heat loss over surfaces that could be insulated (the following is based on U.S. DOE-ITP, 2004):

- Losses occur in energy conversion systems (e.g., power generation, boilers, heat exchangers, process heaters, pumps, motors) where efficiencies are thermally or mechanically limited by materials of construction and equipment design other than insulation.
- In some cases, heat-generating processes are not located optimally near heat sinks, and it may be economically impractical to recover the excess energy.
- Energy is sometimes lost simply because it cannot be stored.
- Energy is also lost from processes when waste heat is not recovered and when waste by-products with fuel value are not utilised.

- Energy may leave the process with the product, cooling water, flue or exhaust gas

Of the energy that is lost over surfaces, the actual loss depends on the specific application. Pipes with a large diameter for example have less heat loss expressed per unit of energy throughput as compared to those with a smaller diameter. In lower temperature processes, energy is consumed mainly via smaller, insulated, steam or hot water based equipment, where losses over the surface area represent a more significant fraction of the energy used.

One of the case studies considered in this study, the coal-fired power plant (see Box 2: case studies), predominantly involves high-temperature surfaces. At a currently typical heat loss rate of 150 W/m^2, this plant would have a heat loss that represents about 0.5% of total energy input. Another case study, the crude distillation tower predominantly involves middle-temperature surfaces. At a currently typical heat loss rate of 150 W/m^2, this tower has a heat loss representing about 6% of total energy input.

Based on these case studies and additional expert judgements, the energy loss over insulated surfaces in fossil fuel-fired power generation is assumed to be 0.5% of energy input. For low, middle, and high-temperature equipment in industry, the heat loss over insulated surfaces is assumed to be 6%, 4% and 2% of energy input, respectively.[1] These shares represent the heat loss in case all surfaces would be insulated up to typical levels. Since a share of the surfaces is currently not insulated, the heat loss over currently insulated surfaces is somewhat lower.

Table 2 - 2, Figure 2 - 3 and Figure 2 - 4 show the current heat loss calculated by combining the shares of heat loss (see above), the current fuel input per temperature level (see section 2.2.1) and the assumptions regarding current insulation (see section 2.1). Results show that for the power sector the absolute heat loss is substantial. Even so, the percentage of heat loss as share of total input is relatively low.

Table 2-2 Current heat loss

Type of application	Total share of energy use input that is currently lost	Share of energy that is lost over currently insulated surfaces	Share of energy that is lost over surfaces without or with damaged insulation
Fossil fuel-fired power generation	1.2%	0.5%	0.7%
Industry			
Low-temperature surfaces (<100 °C)	9.6%	5.4%	4.2%
Middle-temperature surfaces (100 – 300 °C)	6.7%	3.8%	2.9%
High-temperature surfaces (>300 °C)	5.0%	2.0%	3.1%

[1] At equal insulation performance in terms of heat loss rate (W/m^2), the heat loss as percentage of energy input is lower for equipment with higher temperatures, since the energy within such equipment is higher. In addition, the size of higher temperature equipment on average is larger leading to less heat flow over exterior surface per unit of volume. On top of that, the time that a heat medium remains in higher temperature equipment on average is shorter, allowing less time for the medium’s heat content to flow over exterior surface.

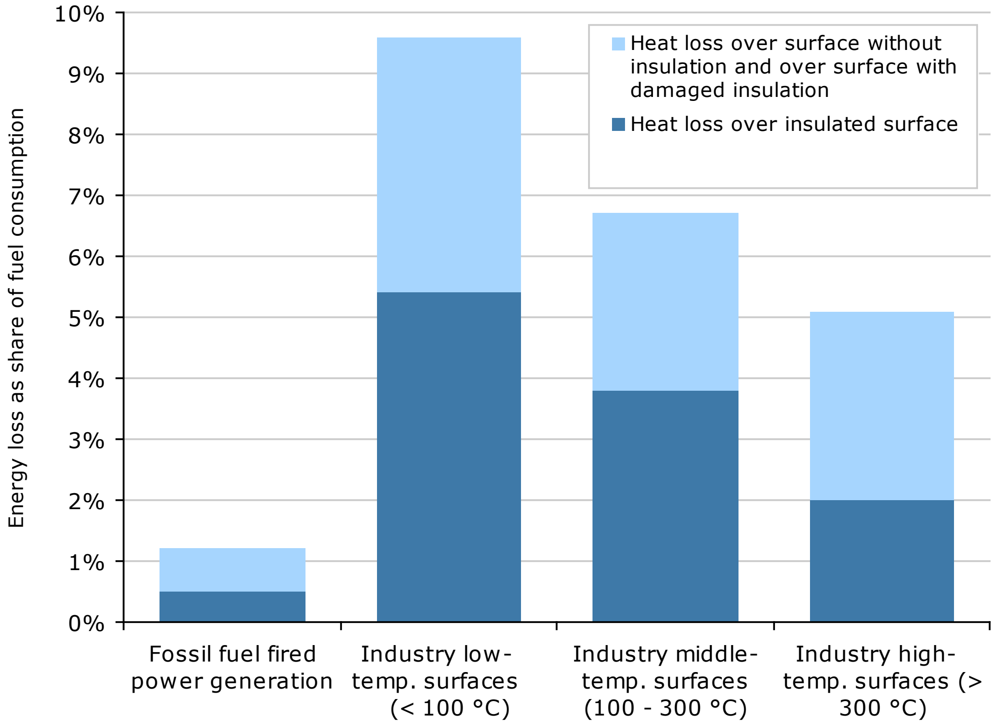

Figure 2-3 Current heat loss as share of fuel consumption in EU27

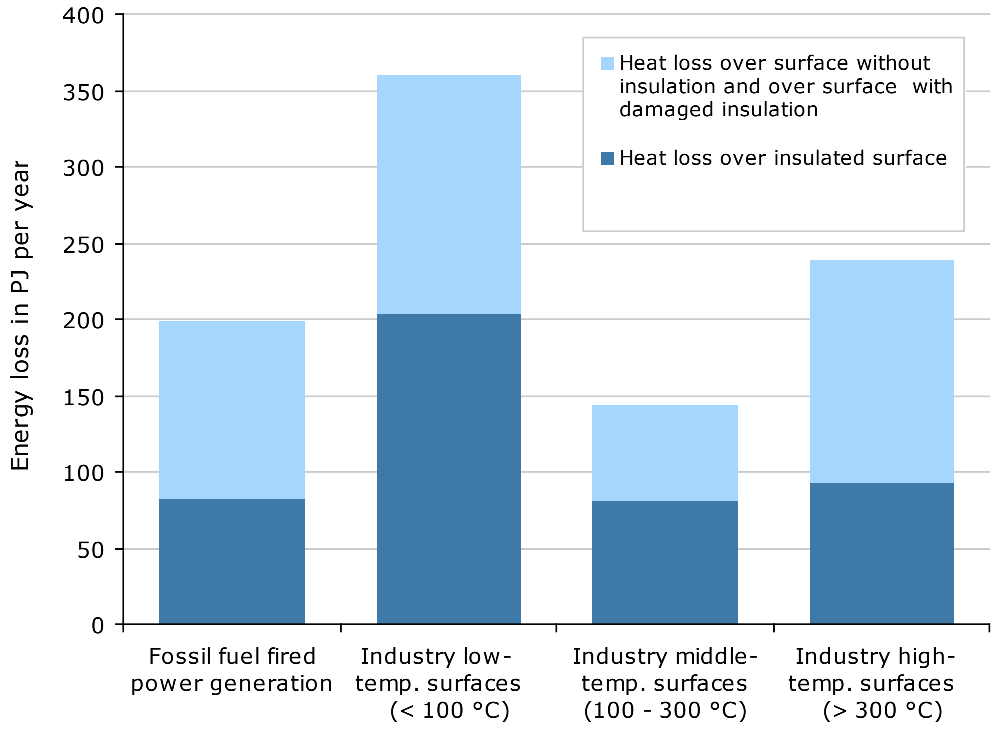

Figure 2-4 Current heat loss over surfaces in EU27

The shares in Table 2 - 2 seem conservative compared to assumptions made by the U.S. Department of Energy (DOE-ITP, 2010) in an energy analysis of U.S. industry. That analysis assumes that energy losses incurred during distribution of steam within the plant boundaries amount to 20% of steam production. Losses during process heating due to radiation, convection, insulation, and cooling are estimated to be 15%. Both types of losses include losses due to missing or damaged insulation.

2.3 Investments in insulation

The annualised investments in insulation over the insulation lifetime are obtained by annualising (section 2.3.2) total investments required to limit heat loss to a certain level (section 2.3.1).

2.3.1 Total investments

Investments in insulation include material costs and installation costs. Material costs include the costs of both insulation material and cladding. The costs of maintenance are not considered in this study.

Figure 2 - 5 shows the typical relation between overall investments and insulation thickness for a pipe. Thicker insulation requires more material (See Box 3 for the relation between insulation thickness and heat loss). Material costs therefore scale with the thickness of the insulation. Costs related to the installation and cladding material are considered to be fixed; each time however that a new layer of insulation material is required, additional effort needs to be made, resulting in a small step in installation costs.

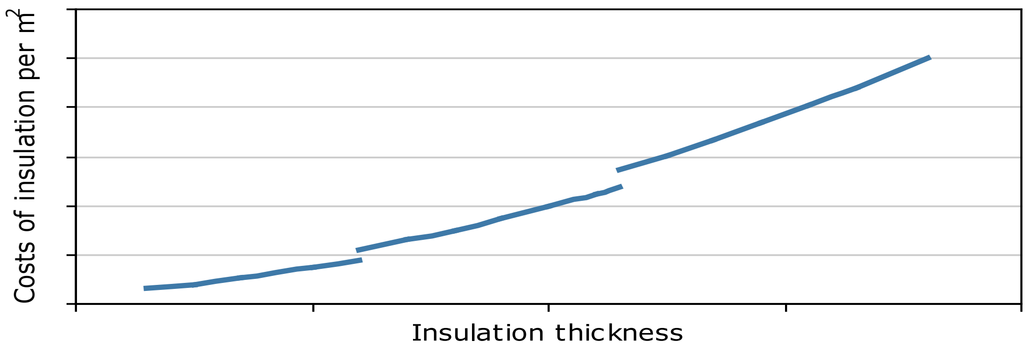

Figure 2-5 Typical required investments in insulation as function of insulation thickness for a pipe

In this study, relations between the costs of insulation (Euro) and the rate of heat loss (W/m^2) are obtained from case studies (see Box 2: Case studies): a coal-fired power plant for high-temperature surfaces, part of a chemical plant for middle-temperature surfaces and part of a brewery for low-temperature surfaces.

Box 3 Relation between insulation thickness and heat loss

The insulation thickness required to attain a certain heat loss rate (expressed as W/m^2 of surface area) is a function of the properties of the insulation material, the shape of the insulated surface, the temperature difference over the insulation layer and the wind speed in the surrounding environment.

The figure below shows the insulation thickness as a function of heat loss rate for case studies prepared by EiiF experts and for various heat pipes with different temperatures and diameters. For the considered applications, the effects of differences in insulation material used and wind speeds are small compared to the effects of temperature differences and shape.

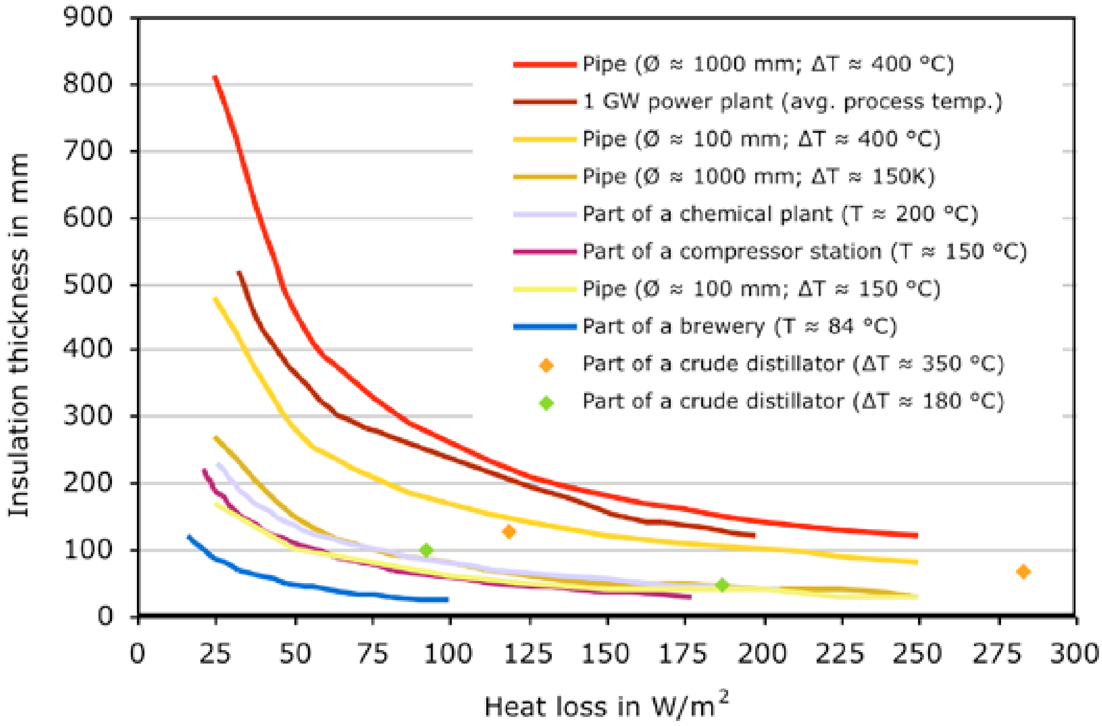

Figure 2-6 Required insulation thickness for different heat loss rates

The figure shows that lower heat loss rates require thicker insulation. In addition, the figure shows that higher temperatures require thicker insulation to reach the same heat loss rate. For the pipes, the figure also shows that the required thickness depends on the pipe diameter. This dependence is a result of the fact that for convex surfaces, such as pipes, the surface area increases with increasing insulation thicknesses.

2.3.2 Annualisation of investments

Installing insulation now saves money in the future. From an investor's point of view it is however impossible to simply add and subtract investments and savings if they occur at different points in time. Investors have a time preference. They would rather have cash immediately than in the future. Like most things that lie ahead in time, future savings are moreover uncertain. This problem is solved in this study by discounting future savings[1]. Table 2 - 3 provides an overview of the assumed discount rate and insulation lifetime.

Table 2-3 Assumptions for the calculation of annual capital costs

Parameter	Value
Discount rate	9%
Lifetime of insulation	15 years

Insulation lifetime varies from one application to the other. Obviously, longer lifetimes increase the profitability of investments in insulation. Based on expert judgments the average lifetime of insulation is estimated to be 15 years; a figure that is supported by Hertel (2011). Insulation of 20 years and older is however also observed in practice. Such insulation generally involves outdated types of materials and therefore should normally be replaced as soon as possible to avoid excessive heat losses.

The discount rate reflects the time preference and risk premium for the investor. When an investor rather receives 100 Euro now then 108 Euro a year from now, then he is said to have a discount rate of 8%. The actual discount rate is the sum of the real discount rate plus the expected rate of inflation. The effects of inflation are excluded from this study by using the real discount rate and expressing all investments, costs and savings in constant 2010 Euros.

The choice of real discount rate depends on the purpose of the analysis. When investigating the potential that is economically attractive from a social perspective, typically a real discount rate of 3 - 5% is used for energy saving investments. When investigating the part of the technical potential that is economically attractive from the point of view of private investors, discount rates of 8-15% or higher can be used to reflect real market conditions (EC, 2009b; Blok 2007; U.S. EPA, 2008). Based on a company survey, Oxera (2009) reports real discount rates of 6 - 9% for low-risk conventional power generation and discount rates of up to 16% for riskier technologies. The PRIMES model used for the official EU projections assumes a real discount of 12% for industry.

A company often bases its hurdle rate (the minimum expected return a company will consider in accepting investment opportunities or action proposals) on its weighted average cost of capital (WACC). Typical WACCs are in the order of 8-10% (Acca, 2006; U.S. EPA, 2008; Damodaran, 2011 and WikiWealth, 2011). Many companies were however found to use hurdle rates that are 3 - 5% higher than their cost of capital (Poterba and Summers, 1995; Meier and Tarhan, 2007). It is worth mentioning here that a firm-wide discount rate would be expected to result in underinvestment in low-risk projects whose expected returns would not meet the company-wide hurdle rate (Oxera, 2011).

Based on the above, a real discount rate of 9% is used which is at the lower bound of typical private discount rates but well above typical social discount rates. The sensitivity to this choice is tested by evaluating heat loss reductions for cost-effective insulation at discount rates of 3% and 15% as well (see Appendix B).

[1] This is equivalent to annualising investments by an annuity factor (α) which is a function of insulation lifetime (n) and discount rate (r):

$$\alpha = \frac{(1+r)^n * r}{(1+r)^n - 1}$$

Box 4 Implicit discount rates

Assuming that companies will implement economically attractive energy efficiency measures, a discount rate can be inferred by looking at what energy efficiency measures are implemented and what not. In other words: the capital costs and (expected) costs savings of implemented and unimplemented projects imply discount rates used by companies. These implicit discount rates typically however significantly exceed market discount rates used by companies. For example, current insulation practices as assumed by this study imply discount rates in the range of 30 - 40%, which is much higher than typical marktet rates used by companies.

Discrepancies between implicit and market discount rates have initiated debates about the effectiveness of the market. One view is that the market currently works efficiently and that the high implicit discount rates must reflect the perceived risk of efficiency investments - an explanation consistent with the hypothesis of efficiently structured markets. On the other hand, technology analysts claim that the high implicit discount rates are the effect of ‘market barriers’ preventing adoption of cost-effective energy-saving technologies (Howarth and Sanstad, 1995; Newell et al., 2006; Jaffe et al. 2004).

This study does not intend to make statements about economic theories and practice. Section 1.3 does however describe some typically observed behaviour that could lead to under-investments and unnecessary heat loss.

2.4 Costs of heat loss

The costs of heat loss are calculated by multiplying heat loss by a price of heat. The heat loss at each level of insulation is determined by multiplying the current heat loss by the ratio between the heat loss at that level of insulation and the current heat loss (-). The relation between this ratio and the rate of heat loss (W/m^2) is obtained from case studies (see Box 2: Case studies): a coal-fired power plant for high-temperature surfaces, part of a chemical plant for middle-temperature surfaces and part of a brewery for low-temperature surfaces.

The price of heat is determined for each sector as the sum of the costs of the fuels used to generate heat and the resulting CO_2 costs. The same price per GJ is used for low-temperature heat and high-temperature heat. The heat price in this study does not include other costs related to the heat generating equipment: investments and costs of operation. These costs amount to approximately 6 Euro/GJ (EiiF, 2011), but are not necessarily avoided through better insulation (see Box 5). Including them in the price of heat would however significantly increase the savings potentials of insulation (see Appendix B).

2.4.1 Costs of fuel

The fuel mix for each sector was obtained from energy statistics (IEA, 2009). Current and future fuel prices were based on a forecasting study of the European Commission (EC, 2009b). Prices of energy exclude effects of taxes and subsidies. Coal, gas and oil prices are assumed to increase by 3%, 2.5%, and 2% per year net of inflation. Baseline fuel prices are shown in Table

2 - 4. To show the effect of accounting for price increases over time, Appendix B shows the calculated potentials at constant fuel and carbon prices.

2.4.2 Costs of greenhouse gas emissions

CO_2 emissions from the combustion of fuels were determined using emission factors according to the IPCC Good Practice Guidance (2006). In Europe, larger industrial installations and power generators are part of the EU emissions trading system (EU ETS). Installations in that system need to balance their CO_2 emissions by emission allowances. Smaller industrial installations, that are not part of the EU ETS, are likely to be faced with alternative climate policies such as carbon taxation also imposing costs on CO_2 emissions.

This study accounts for the effect of climate change policies by assuming costs of 15 Euro/tCO_2 gradually increasing with 2% per year to 20 Euro/tCO_2 in 2025. Table 2 - 4 shows the effect of these costs by including them in the price of fuel. The table demonstrates that the carbon related costs per unit of energy are higher for emission-intensive fuels such as coal (~96 tCO_2/TJ) and oil products (~73 tCO_2/TJ) than for natural gas (~56 tCO_2/TJ).[1]

To show the effect of accounting for price increases over time, Appendix B shows the calculated potentials at constant fuel and carbon prices.

Table 2-4 2010 price of main fuel types (calculated from EC, 2009a using net heating values, average inflation and exchange rate to convert 2008 USD to 2010 Euro)

Fuel type[1,2]	2010 price excl. costs of carbon in Euro/GJ	2010 price incl. costs of carbon[3] in Euro/GJ
Coal	2.57	4.01
Natural gas	6.42	7.26
Oil and oil products	10.21	11.31

[1] The price of renewable fuels, which represent a relatively small part of the total energy supply, was conservatively estimated at 10 Euro/GJ and kept constant throughout time.

[2] The price of purchased heat was taken as the average of the price of gas and coal.

[3] In the calculation the cost of carbon was evaluated at a more detailed classification of fuels than the three fuels shown here.

[1] IPCC Good Practice Guidance (2006); Factors represent averages; the exact emission factors depend on the type of coal and oil product used. In the calculation the cost of carbon was evaluated at a more detailed classification of fuels than the three fuels mentioned here.

Box 5 Costs of investment, maintenance and operation of the heat generating equipment

Improving insulation usually leads to increased capacity since reduction in heat loss allows for increased efficiency: less heat generating equipment is needed to produce the same amount of heat. Including the costs related to heat generating equipment in the price of heat would be justified if the gained capacity can be used effectively or if it can be avoided that excess capacity is built in the first place.

Unfortunately insulation engineers are typically involved at a stage in which equipment design is close to final, the required level of insulation has already been set, and the budget for insulation has been fixed. Even if insulation engineers manage to convince their client of a cost-effective or energy efficient insulation system, the designed heat generation capacity is typically not reduced at a late stage in the design process. In the end, the equipment is usually built with a too low level of insulation and an unnecessary high heat generation capacity. This situation could easily be avoided by involving insulation engineers at an early stage in the design process.

3 Energy savings and CO_2 emissions mitigation potentials

3.1 Overview of different potentials

This study distinguishes three energy savings and CO_2 mitigation potentials:

1) **The potential from insulating currently uninsulated parts and from better maintenance of insulation systems;** Installing insulation on surfaces without insulation and repairing damaged insulation is relatively inexpensive and has typical payback periods of less than a year (see chapter 4 and case studies in Appendix C). The absence of proper insulation is therefore typically not the result of economic considerations but of organisational barriers (see section 1.3).

2) **The potential from improving current insulation to cost-effective levels;** Cost-effective insulation in this study is defined as the insulation that minimises the sum of the costs of heat loss and the costs of insulation (see section 1.4). Companies seldom ask for economical standards, but instead ask for insulation systems that meet safety rules and process needs or result in a generic maximum heat loss rate. This usually leads to insulation levels that are not cost-effective. Cost-effective insulation will therefore not only reduce heat losses, but also save money with respect to current practices. In the past, when fuel prices were lower, this would in many cases not have led to a large difference. Nowadays, the price of energy is higher and is expected to grow even further. As a result there is an increasing gap between current and cost-effective insulation levels.

3) **The potential from improving current insulation to energy efficient levels**; Energy efficient insulation in this study is defined as the insulation at which the sum of the costs of heat loss and the annualised insulation investments are equal to the costs of typical current insulation (see section 1.4). The definition of a cost-effective level is based on the inputs to the calculation of cost-effectiveness: discount rate, lifetime, costs of heat and cost of insulation. Which level of insulation is perceived as cost-effective therefore depends on assumptions about future developments. The future price of energy in particular may be higher than expected. Insulating to energy efficient levels is a way to hedge that risk. Another reason for insulating to energy-efficient levels is that it can help achieve company goals for energy efficiency and emission reduction.

Improved insulation usually requires thicker layers of insulation material. Applying this material is sometimes hampered by limitations in the space available. The spacing between pipes with different temperatures may for instance be too small to allow for sufficient insulation material. This could (partly) be solved by using insulation materials with better insulating properties, but these would typically be associated with increased costs. This drawback can be minimised by involving insulation engineers during early stages of equipment design.

Figure 3 - 1 and Table 3 – 1 show the combined potential from insulating surfaces without or with damaged insulation and from improving current insulation to cost-effective and energy-efficient levels.

The results show that insulating all surfaces to cost-effective insulation would avoid about 66% of current heat loss. Improving insulation to energy-efficient levels would even avoid about 75% of current heat loss. These saving potentials represent about 5% of industrial energy consumption and about 1% of energy input to fossil fuel-fired power plants. Appendix A shows an indicative sectoral and regional breakdown of these potentials. Appendix B assesses the sensitivity of these potentials to a number of key assumptions. Box 6 compares the potentials to values found in literature.

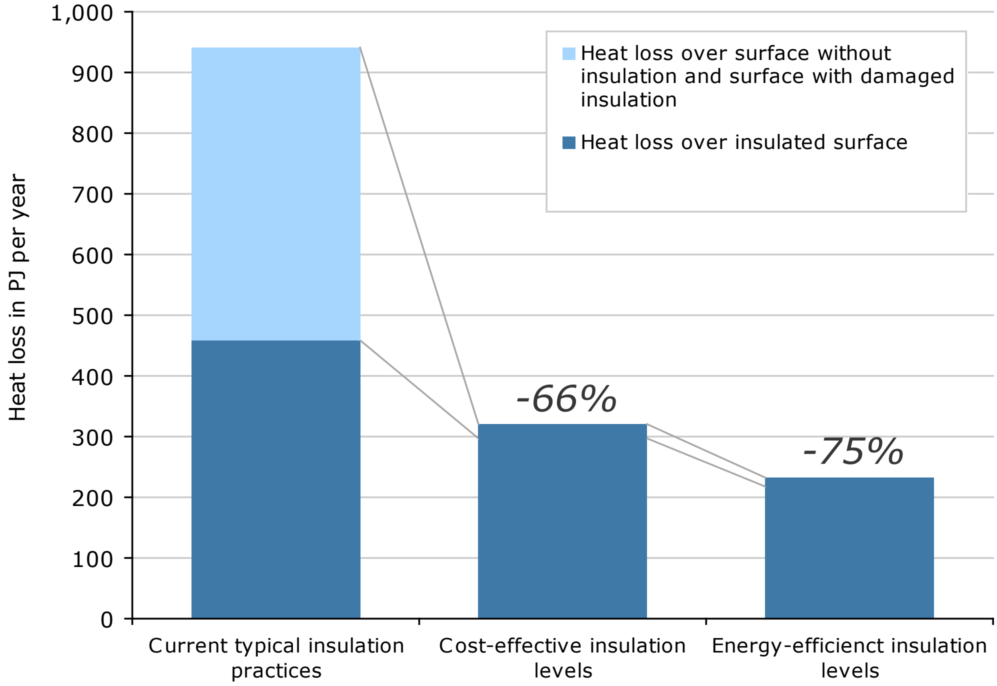

Figure 3-1 Potential from improving current insulation and insulating surfaces without or with damaged insulation; Reductions in heat loss assume insulation of the total surface of all equipment. In reality, a small share of the total surface cannot be insulated due to technical restrictions

Table 3-1 Potential from improving current insulation and insulating surfaces without or with damaged insulation; values have been rounded to two significant numbers; Potentials assume insulation of the total surface of all equipment. In reality, a small share of the total surface cannot be insulated due to technical restrictions

	Annual cost - effective savings potential	**Annual energy - efficient savings potential**
Uninsulated surfaces and surfaces with damaged insulation	460 PJ / 37 Mt CO_2	460 PJ / 37 Mt CO_2
Currently insulated surfaces	160 PJ / 13 Mt CO_2	240 PJ / 19 Mt CO_2
Total	**620 PJ / 49 Mt CO_2**	**710 PJ / 56 Mt CO_2**

Box 6 Literature comparison of total potential

The cost-effective savings potential of about 5% of total industrial energy input found by this study is within the range of literature estimates:

- UBA (2003) estimates that the potential from improving insulation of steam pipes and other steam/hot water related equipment is 0.8% and 1.0 respectively. For furnaces this potential was estimated to be 3%. This is consistent with U.S. DOE-ITP (2007), which estimates that reducing the wall heat losses of furnaces would lead to typical savings of 2- 5%. Assuming that about 40% of all fuel use is related to steam related equipment and 37% for direct process heating (U.S. DOE-ITP, 2010), improving insulation of steam/hot water related equipment and furnaces together can be roughly estimated to save 1.7% of total industry fuel consumption.
- Based on a number of investigated plants, Mauch (2011) preliminary estimates potential savings from technical insulation to be between 0.2 - 0.6% of total fuel consumption and found that savings as reported in literature range from 0.8% to 5%.
- For U.S. industry, on the basis of U.S. DOE's Industrial Assessment Center program, Russell (2002) estimates that potential savings from insulation application and upgrades may reduce fuel consumption anywhere from 3% to 13%.

3.2 The potential from insulating currently uninsulated parts and from better maintenance of insulation systems

Figure 3 - 2 shows the current heat loss over surfaces without or with damaged insulation in European (EU27) fossil fuel-fired power generation and industry. It also shows the heat loss that would occur if these surfaces were insulated to a cost-effective level. In all cases, more than 90% of the current heat loss could be avoided. For high-temperature surfaces, the energy saved is significant even though only 2% of the total surface is assumed to be without or with damaged insulation. Box 7 compares the potentials to values found in literature.

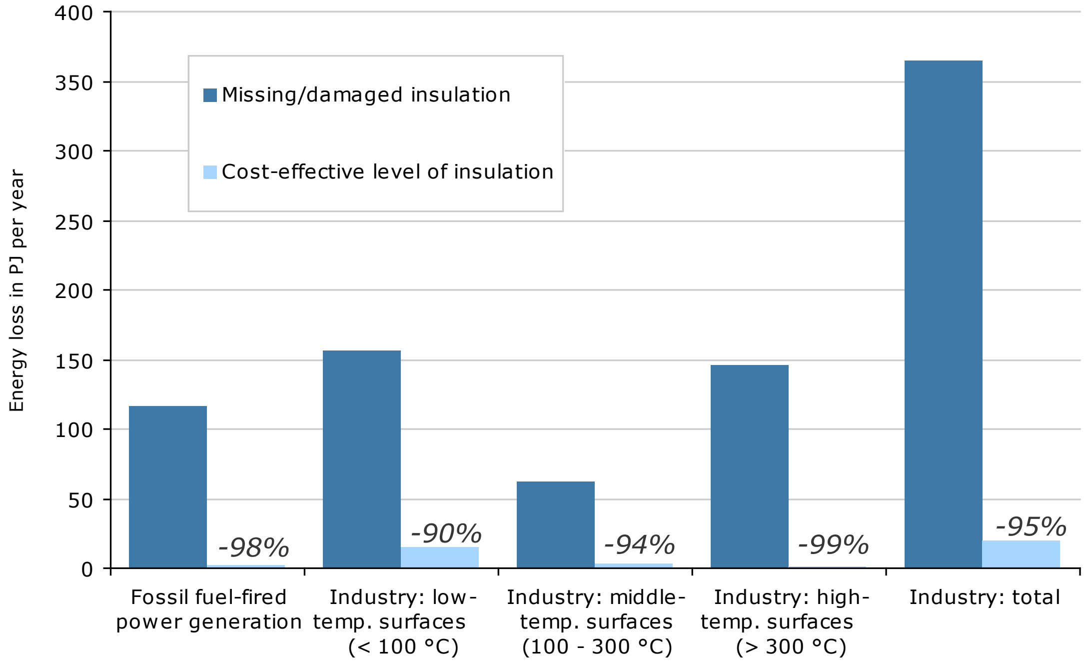

Figure 3-2 Potential in the EU from insulating currently non-insulated and repairing damaged insulation; Reductions in heat loss assume insulation of the total surface of all equipment. In reality, a small share of the total surface cannot be insulated due to technical restrictions

Box 7 Literature comparison of potential from insulating currently uninsulated parts and from better maintenance of insulation systems.

The savings given above are consistent with the limited literature available. Insulation is reported to reduce radiative heat loss from surfaces by 90 % (Hart, 2001).

Table 3 - 2 shows the result of an analysis of the database of U.S. DOE's Industrial Assessment Center program (IAC, 2011). The table lists a selection of relevant measures, together with the savings of each measure expressed as share of the total fuel use of the plants to which a specific measure was recommended. Taking into account that often multiple measures can be applied to a single plant, the savings from these measures are in the same order of magnitude as the 3.2% found in this study.

Table 3-2 Fuel savings from measures that involve applying insulation to bare surfaces or repairing insulation (Analysis of IAC database, 2011); savings are expressed as share of the total fuel use of plants to which a measure was recommended after an audit.

Insulation measure	Savings as share of total fuel use
Insulation in furnaces to facilitate heating / cooling	2.2%
Repair faulty insulation in furnaces, boilers, etc	1.2%
Install / repair insulation on condensate lines	0.8%
Insulate feedwater tank	0.6%
Insulate steam / hot water lines	0.6%
Repair faulty insulation on steam lines	0.2%
Insulate bare equipment	1.2%

3.3 The potential from improving insulation of currently insulated surfaces

Figure 3 - 3 and Figure 3 - 4 compare current heat loss rates to heat loss rates in case of cost-effective and energy-efficient insulation for five normalised case studies (see Box 2 in section 1.4) at 5 Euro/GJ heat and 10 Euro/GJ heat. The figures show that heat loss over insulated surfaces can be significantly reduced compared to current average rates. With higher heat prices, the level of insulation that can be installed cost-effectively is higher, leading to lower heat loss rates.

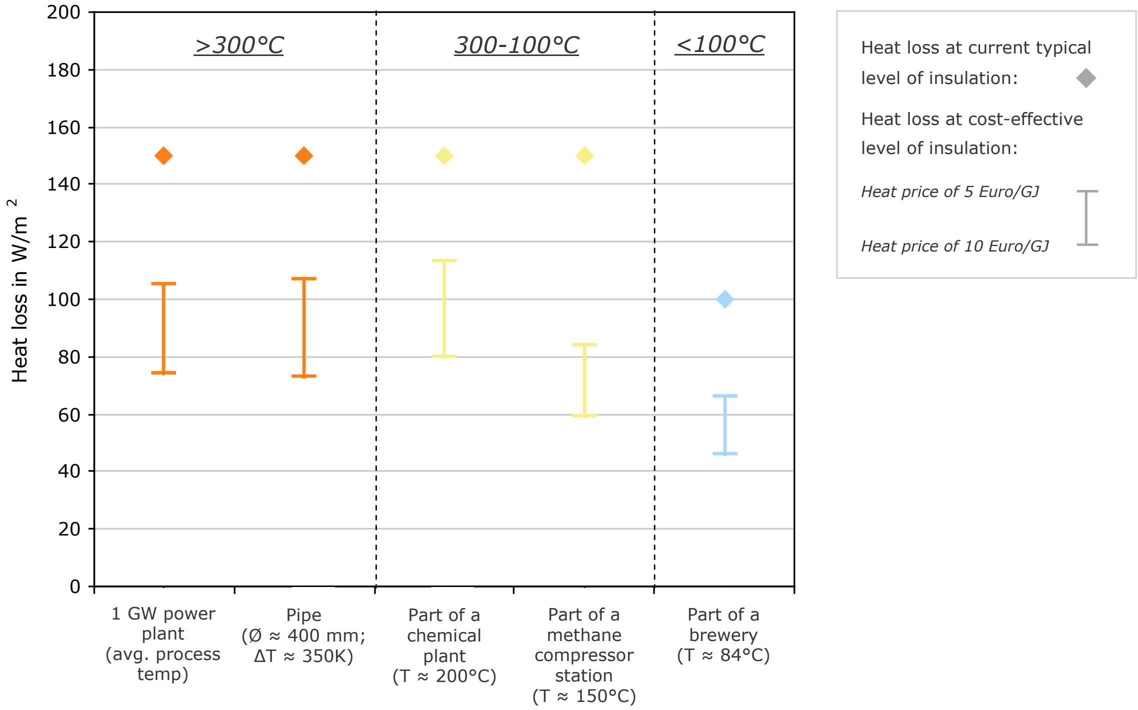

Figure 3-3 Comparison of heat loss rates resulting from cost-effective insulation and typical current insulation

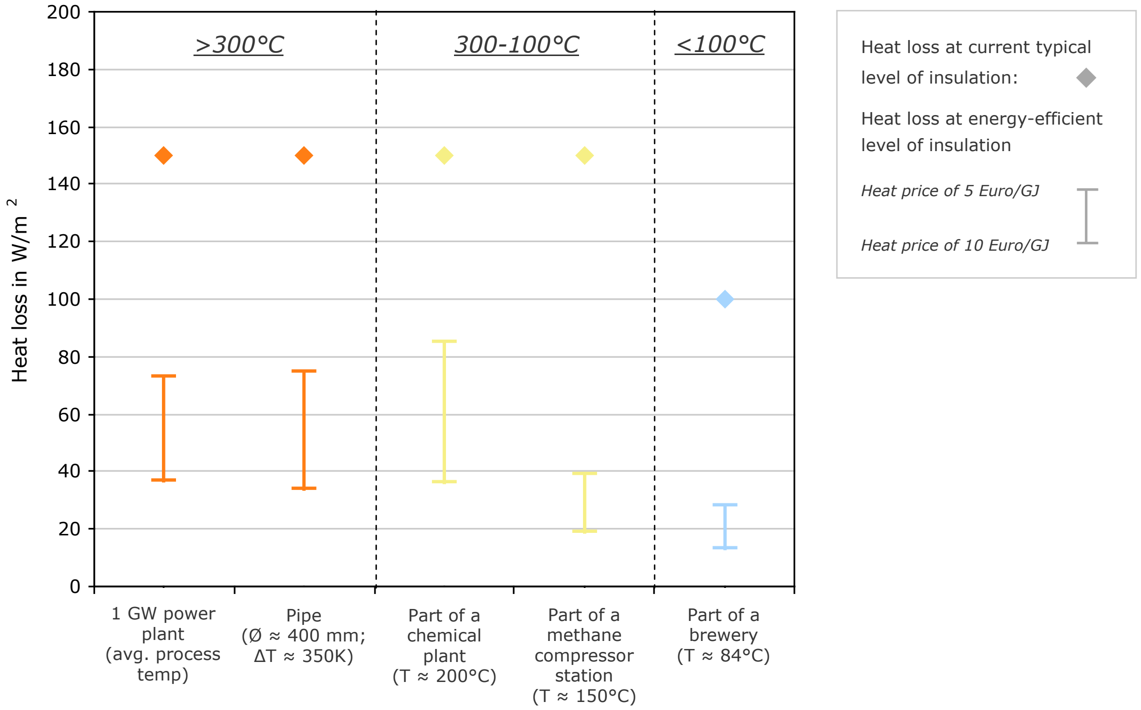

Figure 3-4 Comparison of heat loss rates resulting from energy-efficient insulation and typical current insulation

Figure 3 - 5 shows the current heat loss for insulated surfaces in European (EU27) fossil fuel-fired power generation and industry. The figure also shows the heat loss in case these surfaces would be insulated to cost-effective and energy-efficient levels. The figure does not show losses over surfaces without or with damaged insulation. The figure shows that savings can be attained at all temperature levels. For industry, the savings potential for low-temperature surfaces is about equal to the potentials for middle and high-temperature surfaces together. Appendix B assesses the sensitivity of these results to a number of key assumptions.

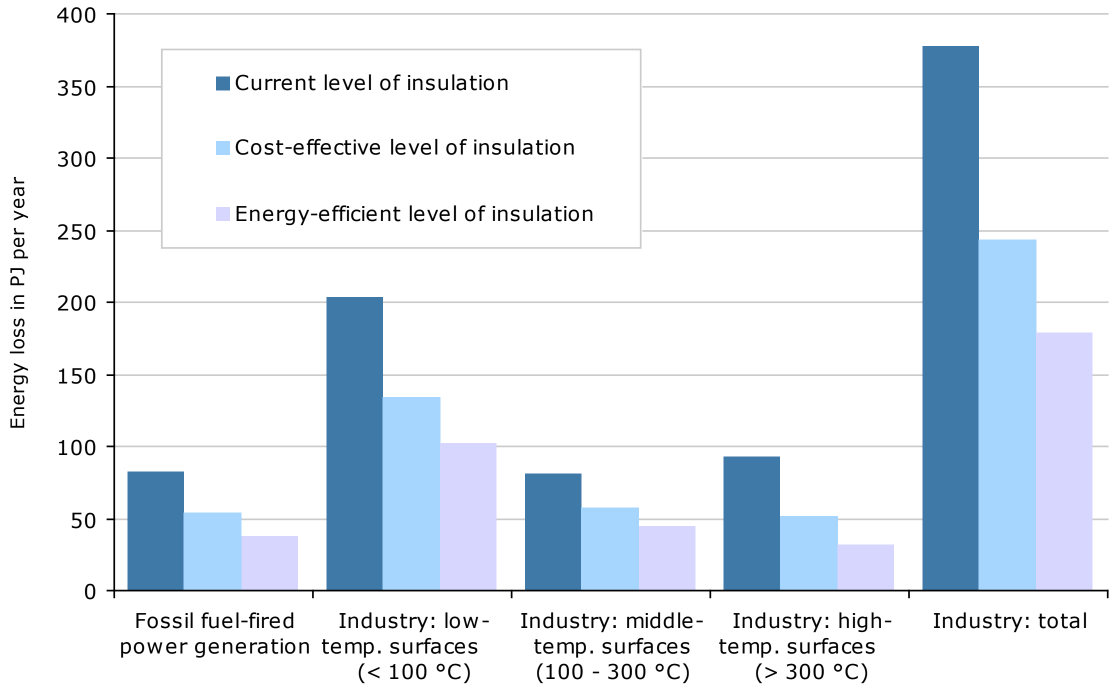

Figure 3-5 Heat loss at current, cost-effective and energy-efficient level of insulation in EU27. Losses over surfaces without or with damaged insulation are not included

Box 8 Literature comparison of potential from improving current insulation to cost-effective levels

Savings found in this study are consistent with expert opinions and with an analysis of the database of U.S. DOE's Industrial Assessment Center program (IAC, 2011). Table 3 - 3 shows the results of this analysis for measures that involved improving insulation. The potential savings are valid for audited plants that were recommended to take specific measures. Overall the results of the analysis suggests a somewhat larger potential than the 1.3% found in this study, but the average level of insulation in Europe is known to be higher than in the U.S.

Table 3-3 Fuel savings from measures that involve improving insulation to optimum levels (Analysis of IAC database, 2011); savings are expressed as share of the total fuel use of plants to which a measure was recommended after an audit.

Insulation measure	Savings as share of total fuel use
Increase insulation thickness	3.0%
Use optimum thickness insulation	4.4%
Use economic thickness of insulation for low temperatures	1.3%

4 *Investments and employment*

4.1 Investments

Figure 4 - 1 shows investments required to improve insulation to cost-effective and energy-efficient levels together with the corresponding annual savings from reduced heat loss. Table 4 - 1 shows the required investments and average simple payback periods.

The results show that on average the savings from improving insulation to cost-effective and energy-efficient insulation levels over total insulation lifetime (estimated to be 15 years on average; see section 2.3) more than balances the additionally required initial investments. Investments in projects targeted at surfaces without or with damaged insulation will on average even be earned back in less than a year. Such short simple payback periods[1] are in line with periods reported in literature (see e.g. King, 2010; Russell, 2002 and case studies in Appendix C) and what experts find in practice.

Replacement of current insulation by better insulation on average has payback periods of 5 – 10 years. Such projects are typically not implemented by companies. The savings potential from improving current insulation is therefore best realised during general overhauls and installation of new equipment when new insulation needs to be applied anyway. This does not mean that removal and replacement of currently applied insulation is never financially attractive. Depending on the application and age, state and thickness of currently applied insulation, payback periods may be much shorter than 5 years.

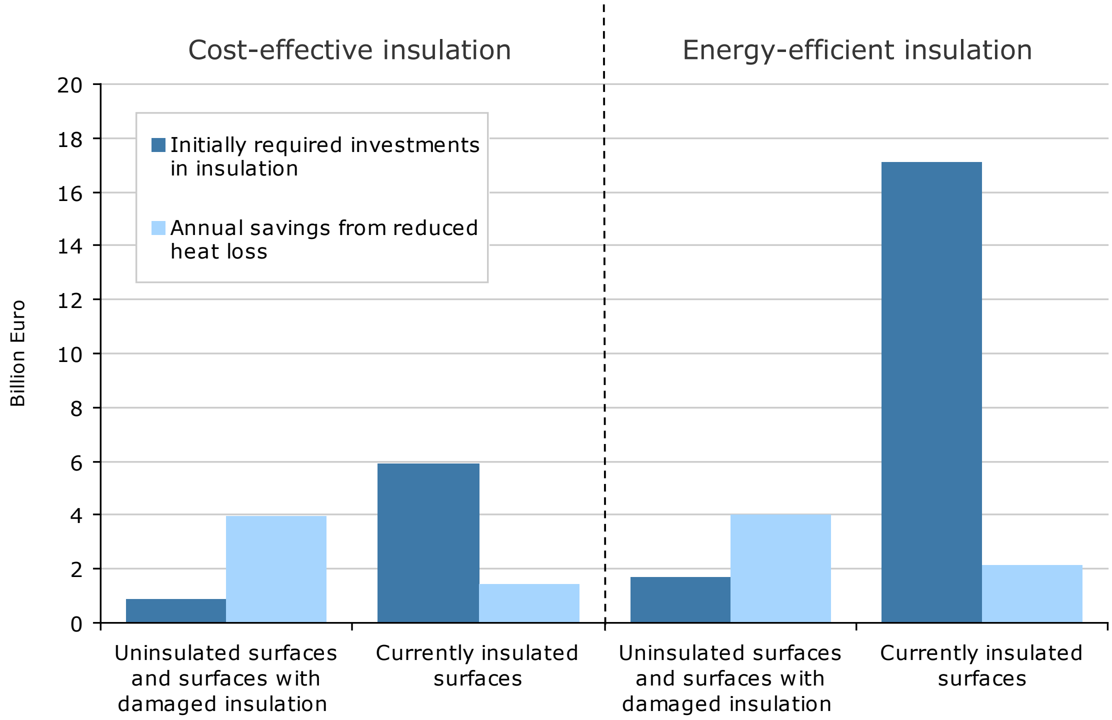

Figure 4-1 Investments required for improving insulation to cost-effective and energy-efficient levels and corresponding annual savings from reduced heat loss; Costs for any removal of old insulation were not considered.

1 The simple payback period of a project is the required investment divided by the difference between its annual benefits and costs. By dividing the difference in investment costs by the difference in the costs of lost energy, a simple payback time can be calculated for improving the current insulation by cost-effective insulation.

Table 4-1 Investments required for improving insulation to cost-effective and energy-efficient levels; values have been rounded to billions

	Investments required for cost - effective insulation (Billion Euro)	Investments required for energy – efficient insulation (Billion Euro)
Uninsulated surfaces and surfaces with damaged insulation	1 (avg. SPP[1]: 0.2 years)	2 (avg. SPP: 0.4 years)
Currently insulated surfaces[2]	6 (avg. SPP: ~4 years)	17 (avg.SPP: ~8 years)
Total required investments	**7**	**19**

[1] SPP: simple payback period; required investment divided by the difference between its annual benefits and costs.
[2] Costs for any removal of old insulation were not considered.

Figure 4 - 2 compares costs of heat and investments related to typical current insulation and cost-effective insulation. The costs and savings of heat loss are totals over an insulation lifetime of 15 years and take into account energy price increases (see section 2.4). Future benefits have not been discounted.

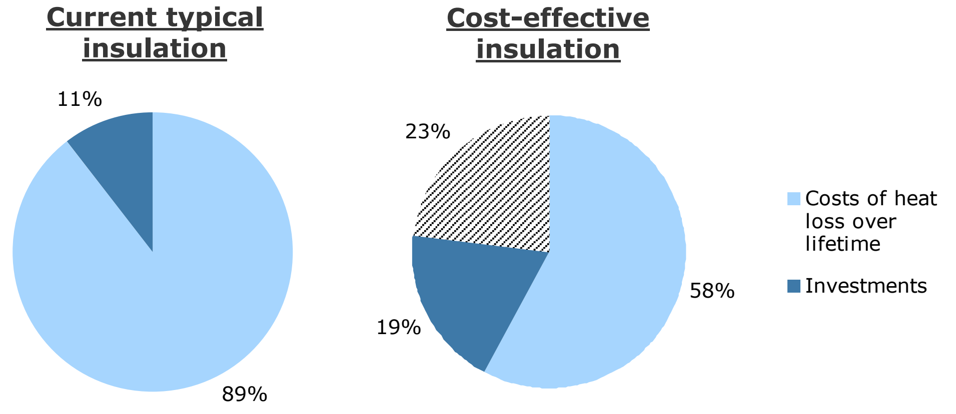

Figure 4-2 Visualisation of cost savings from reduced heat loss for an average insulated surface

The figure shows that cost-effective insulation requires a higher initial investment, but, because of cost savings from reduced energy loss, will over the total insulation lifetime lead to lower costs.

Costs for current typical insulation:

11% investment in insulation + 89% costs for energy due to heat loss = 100%

Costs for cost-effective insulation:

19% investment in insulation + 58% costs for energy due to heat loss = 77%

The cost-savings that can be achieved depend on characteristics of the specific application. As a general rule, the achievable cost savings of improved insulation increase with longer operation times and lifetimes.

4.2 Employment

Improvement of insulation not only leads to energy savings but also saves jobs and will create new jobs because of additional investments in energy efficiency.

Current insulation levels could gradually be improved to cost-effective levels over the next 15 years; the average insulation lifetime used in this study. Table 4 - 1 shows that this improvement can be expected to be accompanied by additional investments of roughly 6 billion Euros (or about 0.4 billion Euros per year). Further it is assumed that with every additional 100,000 Euros of turnover the insulation industry hires one additional employee. Under these assumptions, it follows that cost-effective insulation has the potential to lead to a structural increase in employment by about 4,000 people EU wide. A similar assessment for energy-efficient insulation will lead to even higher estimates.

5 *Conclusions and recommendations*

5.1 Size of the potential

A savings potential was found to exist across all regions, sectors and equipment operating temperatures. Potentials vary between regions and sectors, due to differences in energy use, temperature profiles and fuel mix.

The results show that about two thirds of the energy and emission saving potential is in uninsulated or damaged insulation. The remaining part of the potential would come from improving insulation on currently insulated surfaces. Insulating all surfaces to cost-effective insulation would avoid about 66% of current heat loss. This corresponds to about 620 PJ (about ~480 PJ for industry and ~140 PJ for fossil fuel-fired power plants). Improving insulation to energy-efficient levels would even avoid about 75% of current heat loss, corresponding to about 710 PJ (~550 PJ for industry and ~160 PJ for fossil fuel-fired power plants). Saving potentials represent about 5% of industrial energy consumption and about 1% of energy input to fossil fuel-fired power generation. Potentials may be substantially higher or lower for individual plants.

The order of magnitude of the total savings potential shows that technical insulation can significantly contribute to achieving EU's 2020 climate and energy targets, known as the "20-20-20" targets: a reduction in EU greenhouse gas emissions below 1990 levels and a 20% reduction in primary energy use compared with projected levels by improving energy efficiency. Improving insulation will not only save energy but also costs and could have a positive effect on employment.

The results of this study are endorsed by insulation experts and are reasonable when tested against results of real insulation projects. Since the number of insulation projects available for this study did not allow robust statistical analyses, the found potentials should nevertheless be regarded as indicative estimates.

5.2 How to tap the potential?

This study shows that insulating uninsulated equipment and repairing damaged insulation parts combines the biggest energy and emission cost-effective savings potential with payback periods of less than one year. It is therefore recommended that industry focuses first on those uninsulated and damaged parts which can be insulated quickly and easily and bring immediate benefits.

Compared to current typical insulation practices, cost-effective insulation will save both energy and money. It is therefore recommended that cost-effectiveness is evaluated in future projects. Since insulating now, saves money in the future, the cost-effectiveness should be evaluated using expected future costs of energy.

Removal and replacement of current insulation is attractive under some circumstances. Replacing damaged insulation or insulating bare equipment is normally always cost-effective. The savings potential of improving current insulation to cost-effective levels is therefore best realised during general overhauls and installation of new equipment.

During general overhauls and installation of new equipment, it is recommended that insulation beyond cost-effective levels is also considered. Insulating beyond cost-effective levels is a way to partly mitigate the risks of increasing energy prices and can help achieve company goals for energy efficiency and emission reduction.

According to experts, the present absence of cost-effective insulation is partly the result of organisational barriers. To realise the potential of improved insulation, it is therefore recommended that these barriers are identified and tackled where they exist.

Application of insulation material is quite often hampered by limitations in the space available, for example between pipes with different temperatures. To avoid this problem, it is recommended that insulation engineers are involved at an early enough stage in the design phase of new equipment or retrofit projects.

6 *Reference sources*

[1] Acca, “The cost of capital in Europe: an empirical analysis and the preliminary impact of international accounting harmonization,” Certified Accountants Educational Trust for the Association of Chartered Certified Accountants, London, 2006;

[2] Barnett, G.P., “Designing factors,” Steam Digest, Volume IV, 2003, pp. 13-18

[3] Blok, K., “Introduction to Energy Analysis,” Techne Press, Amsterdam, 2007

[4] Damodaran, Cost of Capital per Sector, Data used: Value Line database of 5928 firms; Data used is as of January 2011, http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/wacc.htm (accessed August 2011)

[5] EC, “EU energy trends to 2030,” European Commission, 2009a

[6] EC, “Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries,” European Commission, 2009b

[7] ECN, “Transitie naar een duurzame energievoorziening in 2050; Evolutie of Revolutie?” Energieonderzoek Centrum Nederland, October 2002.

[8] EiiF, Expert meeting in November 2010, European Industrial Insulation Foundation, 2010a

[9] EiiF, Questionnaire to insulation experts on level of awareness and current insulation performance, European Industrial Insulation Foundation, 2010b

[10] EiiF, standard specifications of six companies (four in the power sector, one in the brewery sector and a provider of boiler systems, provided by European Industrial Insulation Foundation, 2010c

[11] EiiF, questions to technical experts on first results, European Industrial Insulation Foundation, March 2011

[12] EiiF, text on cold insulation based in the following data sources:

- AGI Q 03: Thermal insulation – Execution of thermal and cold insulations – Insulation work on industrial installations
- AGI Q 157-7: Cold protection – Polyurethane in-situ foam, insulation layer thicknesses to prevent condensation, cold losses, masses
- DIN 4140: Insulation work on industrial installations and building equipment – Execution of thermal and cold insulations
- FESI Technical Lexicon (available at http://cms.fesi-insulation.eu/_private/PDFs/Lexicon/Lexicon.pdf) accessed March 2012
- Technische Briefe der BFA Wärme-, Kälte-, Schall- und Brandschutz im Hauptverband der Deutschen Bauindustrie e.V. 10898 Berlin
- Nr. 7 “Grundlagen der Kälteisolierung – Principles of cold insulation”, (July 2009, 3. überarbeitete Auflage)

- Nr. 8 “Auslegung der Kälteisolierung zur Tauwasserverhütung auf der Oberfläche – Design of cold insulation to prevent formation of condensation on the surface”, (November 2011, 3. überarbeitete Auflage)

[13] European Industrial Insulation Foundation, April 2012

[14] EURIMA, “U-Values; For better energy performance of buildings,” report established by Ecofys for the European Insulation Manufacturers Association, 2007

[15] FfE, “Ganzheitliche dynamische Bewertung der KWK mit Brennstoffzellentechnologie,” Forschungsstelle für Energiewirtschaft e.V., München, November 2007.

[16] FfE, “Energiezukunft 2050; Teil 1 – Methodik und IST-Zustand,” Forschungsstelle für Energiewirtschaft e.V., München, October 2009.

[17] Hart, G., “Best Practices in Steam System Management,” Steam Digest 2001, pp. 11-15

[18] Hart, G., “Insights for insulation installation,” Steam Digest, Volume IV, 2003, pp. 19-26

[19] Hertel website, Industrial Thermal Insulation; Power & Utilities, http://www.hertel.com/en/power-and-utilities/insulation/thermal-insulation.html (accessed August 2011)

[20] Howarth, R.B. and Sanstad, A.H. “Discount rates and energy efficiency,” Contemporary Economic Policy, Volume 13, Issue 3, July, 1995

[21] IAC Database, Industrial Assessment Centers Database containing 15,079 assessments and 113,083 Recommendations, available at http://iac.rutgers.edu/database/, downloaded August 2011

[22] IEA, 2007 energy statistics, International Energy Agency, 2010

[23] IPCC, Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, International Panel of Climate Change, 2006

[24] Jaffe, A.B., Newell, R.G. and Stavins, R.N., “Economics of Energy Efficiency,” Encyclopedia of Energy, Volume 2, Elsevier Inc., 2004

[25] KAEFER, 2010, “Optimum insulation layer thickness distribution leads to enhanced profitability,” KAEFER Corporate Technology & Research, Technical Information, No. CTR-T 10 101 EN, 2010 (provided by EiiF)

[26] King, R.L., “Mechanical Insulation Maintenance: A Proven Investment Opportunity Hidden in Plain Sight,” Insulation Outlook, December 2010.

[27] Lettich, M.J., “Insulation Management and Its Value to Industry,” Steam Digest, Volume IV, 2003, pp. 27-32

[28] Mauch, W., “Energieeinsparpotenzial durch technische Dämmung,” FIW Wärmeschutztag, Forschungsstelle für Energiewirtschaft e.V., 26 May 2011

[29] Meier, I. and Tarhan, V., “Corporate investment decision practices and the hurdle rate premium puzzle,” Working Paper, 2007, as cited by Oxera (2011)

[30] NCTI (2011); Article on website: “Hoe duurzaam is groen?” (available at http://www.ncti.nl/index.php?pageid=8&lang=&parentid=8#50); accessed January 2010

[31] Newell, R.G., Jaffe, A.B. and Stavins, R.N., “The effects of economic and policy incentives on carbon mitigation technologies,” Energy Economics, 28, 2006, pp. 563–578

[32] Oxera, “Discount rates for low-carbon and renewable generation technologies,” prepared for the Committee on Climate Change, April, 2011

[33] Poterba,J. and Summers, L., “A CEO Survey of U.S. Companies’ Time Horizons and Hurdle Rates,” Sloan Management Review, Fall, 1995, pp 43-53, as cited by Oxera (2011)

[34] Russell, C, “Insulation Improves Economic Returns in Manufacturing,” Steam Digest, Volume III, 2002, pp. 35-36

[35] UBA, “Möglichkeiten, Potenziale, Hemmnisse und Instrumente zur Senkung des Energieverbrauchs branchenübergreifender Techniken in den Bereichen Industrie und Kleinverbrauch,” Prepared by Fraunhofer Institut and Forschungsstelle für Energiewirtschaft e.V. for Umweltbundesambt Germany, Karlsruhe/München, Juli 2003

[36] U.S. DOE-ITP, “Improving Process Heating System Performance: a sourcebook for industry,” Second Edition, U.S. Department of Energy, Industrial Technologies Program, 2007

[37] U.S. DOE-ITP, “Manufacturing Energy and Carbon Footprint,” Prepared for the Industrial Technologies Program (ITP) by Energetics Incorporated, version December 2010 (available at http://www1.eere.energy.gov/industry/rd/footprints.html)

[38] U.S. EPA, “Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy-Makers,” Energy and Environmental Economics, Inc. and Regulatory Assistance Project, November 2008.

[39] VDI, “Thermal insulation of heated and refrigerated operational installations in the industry and the building services; Calculation rules,” VDI 2055, Verein Deutscher Ingenieure, September 2008.

[40] WikiWealth, Industrial and Energy Industry Research & Analysis, based on largest 30 companies in each industry, http://www.wikiwealth.com/wacc (real-time data; accessed August 2011)

A Breakdown of potential by sector and region

A.1 Potential per sector

Figure A - 1 shows the distribution of the energy and emissions savings potential over different sectors. The saving potentials per sector have been calculated on the basis of overall energy use, temperature profile and the fuel mix. Differences in typical investments in insulation and insulation maintenance have not been considered since no data to support analyses of such aspects were available. It is stressed that potentials per sector were not obtained from detailed sector-specific investigations and can therefore only be used as indicative estimates.

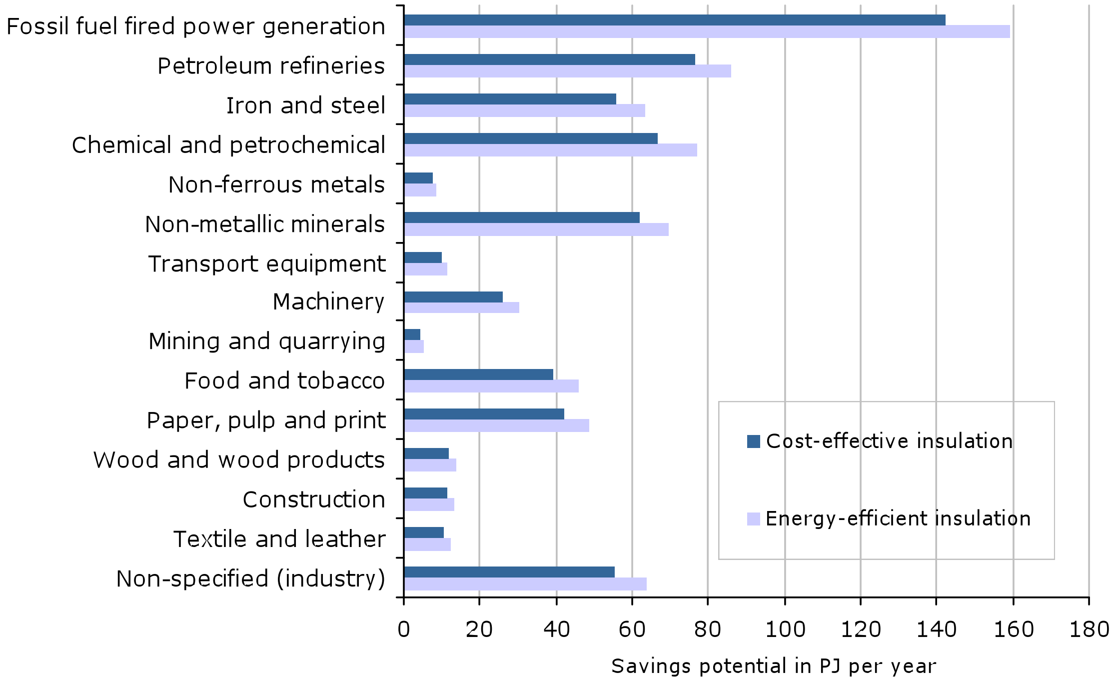

Figure A-1 Annual energy and emissions savings potential per sector

A.2 Potential per region

To assess the geographical distribution of the savings potential, the countries in EU27 are grouped in four regions (see Figure A - 2).

Figure A-2 Regional division of EU27 for the purpose of this study

Figure A - 3 shows the annual energy and emissions savings potential for each region. The saving potentials per region have been calculated on the basis of overall energy use, sector temperature profile and the fuel mix. Differences in typical investments in insulation, insulation maintenance and regional differences in temperature profiles have not been considered since no data to support analyses of such aspects were available. It is stressed that potentials per region were not obtained from detailed region-specific investigations and can therefore only be used as indicative estimates.

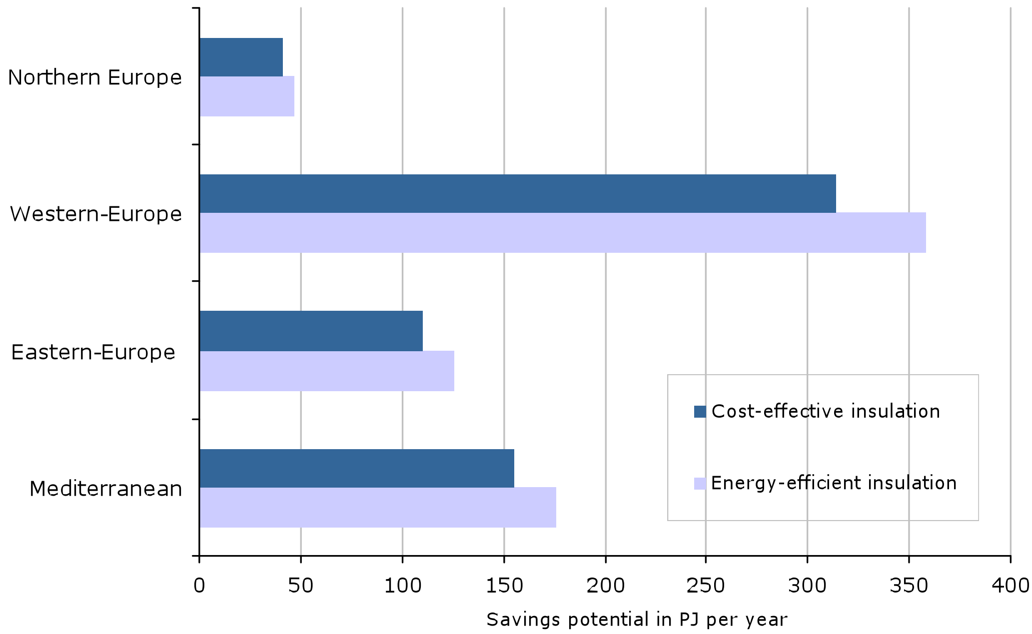

Figure A-3 Annual energy and emissions savings potential per region

B *Sensitivity analyses*

B.1 Missing and damaged insulation

Table B - 1 shows the savings potential of cost-effective insulation for different assumptions of the shares of surface without or with damaged insulation. The table shows that:

- the savings potential of insulating surface without or with damaged insulation strongly increases with the increased presence of such surfaces
- For all assumed shares of uninsulated surfaces, the potential of insulating such surfaces is larger than that of improving insulation of surfaces that are already insulated
- The potential from improving insulation of surfaces that are already insulated slowly decreases since a higher share of uninsulated surface means a lower share of insulated surfaces.

Table B-1 Savings potentials for different shares of surfaces without or with damaged insulation.

Share of surface without or with damaged insulation: low-temp./mid-temp./ high-temp. surfaces	Savings potential of improving insulation to cost-effective levels of surfaces that are already insulated in PJ/year	Savings potential of insulating surfaces without or with damaged insulation to cost-effective levels in PJ/year
6 / 3 / 1	167	244
10 / 6 / 2	162	459
15 / 10 / 4	156	823

B.2 Cost-effective insulation

A sensitivity analysis was performed to investigate the effect of different assumptions regarding the discount rate (see section 2.3.2) and price of energy (see section 2.4). The reason for checking the effects of these two specific parameters is that an investor can choose what discount rate and heat price is used when calculating the profitability of an investment.

Table B - 2 shows the result of this analysis. The upper value in the table shows the average cost-effective heat rate over all surfaces. The lower value in each cell shows the total EU cost-effective savings potential for all sectors considered. The table only considers surfaces that currently are insulated and not surfaces without or with damaged insulation.

The middle cell shows the potential under the assumptions used by this study. These assumptions intend to reflect real market conditions and therefore result in a potential from a private perspective. The top left cell shows the potential that is economically attractive from a social perspective.

The table shows that lower discount rates and higher heat prices lead to higher levels of cost-effective insulation and a greater cost-effective potential. In addition, the table shows that taking into account costs related to the heat generating equipment has a much greater impact than assuming a moderate price increase over time. The most important conclusion to be drawn from the table however is that there exists a significant cost-effective potential over a wide range of assumptions.

Table B-2 Cost-effective rate of heat loss (upper value) and savings potential (lower value) for different assumptions regarding discount rate and price of energy.

Discount rate	Costs of heat remain constant over time	Costs of heat increase over time*	Costs of heat increase over time and take into account costs of heat generating equipment (6 Euro/GJ)
3%	52 W/m^2 185 PJ	49 W/m^2 195 PJ	38 W/m^2 229 PJ
9%*	64 W/m^2 151 PJ	60 W/m^2 162 PJ	46 W/m^2 209 PJ
15%	76 W/m^2 118 PJ	72 W/m^2 129 PJ	55 W/m^2 180 PJ

* Assumptions used in this study.

B.3 Energy-efficient insulation

Similar to the case for cost-effective insulation, a sensitivity analysis was performed to investigate the effect of different assumptions regarding the discount rate (see section 2.3.2) and price of energy (see section 2.4). Rate of heat loss (upper value) at energy-insulation levels and corresponding savings potential (lower value) for different assumptions regarding discount rate and price of energy. Table B - 3 shows the result of this analysis. For a description of the table, the reader is referred to the previous section. Again the most important conclusion is that there is significant potential over a wide range of assumptions.

Table B-3 Rate of heat loss (upper value) at energy-insulation levels and corresponding savings potential (lower value) for different assumptions regarding discount rate and price of energy

Discount rate	Costs of heat remain constant over time	Costs of heat increase over time*	Costs of heat increase over time and take into account costs of heat generating equipment (6 Euro/GJ)
3%	24 W/m^2 266 PJ	22 W/m^2 275 PJ	14 W/m^2 302 PJ
9%*	35 W/m^2 232 PJ	32 W/m^2 243 PJ	19 W/m^2 284 PJ
15%	48 W/m^2 191 PJ	44 W/m^2 205 PJ	26 W/m^2 261 PJ

* Assumptions used in this study.

C Best practice in industry

Every theory becomes more convincing if executed example cases from the real world can be presented alongside it. This is why the EiiF collected the following examples from her Partners & Members. Each of them clearly supports the message put forward in this study. Considering that the examples presented here are all situated in countries that are known for having a better-than-average insulation standard, it is fair to assume that the situation in the whole of Europe will have an even greater potential than the one that is painted here.

C.1 Chemical plant, France

A TIPCHECK energy audit was performed on a chemical plant in France by an EiiF Founding Partner. The auditing consisted of just one employee, spending two weeks on-site and taking over 400 thermal images for the final audit report. These were the most important findings:

Safety

Situations were located where a high risk of burn damage exists to the personnel. In the first image, the thermographic picture shows a dangerously hot surface temperature of more than 138 °C on a boiler window, situated right next to a ladder support.

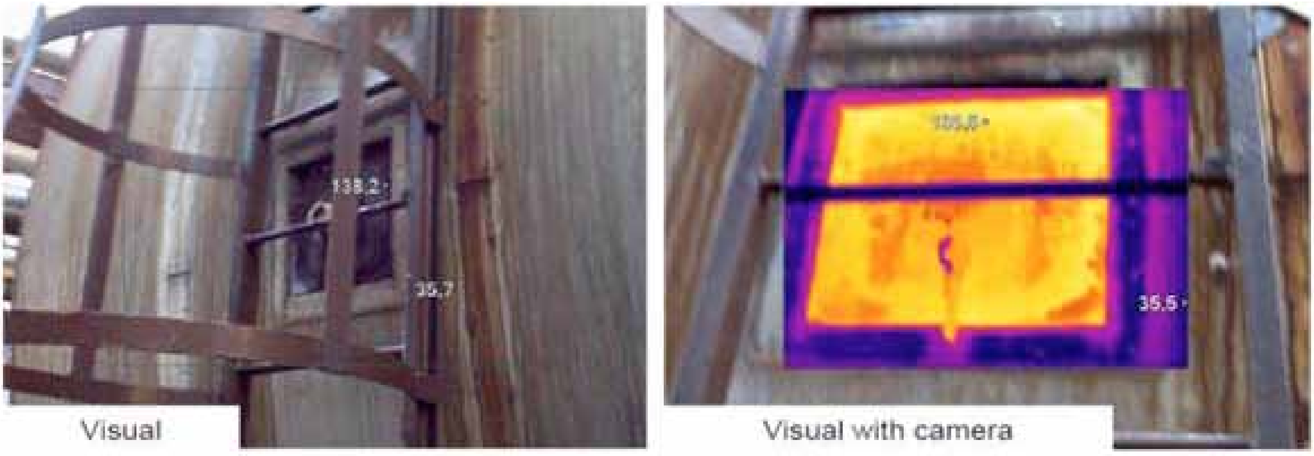

Figure C-1 Regular and thermographic photo of a boiler window

Energy efficiency & environment – valves

Secondly, about 30 uninsulated valves were found that not only pose a severe burn risk for personnel, but also cause a large loss of energy. Instalment of mattress insulation on these parts ensures temperatures of below 50°C, which is safe to be handled by personnel wearing gloves.

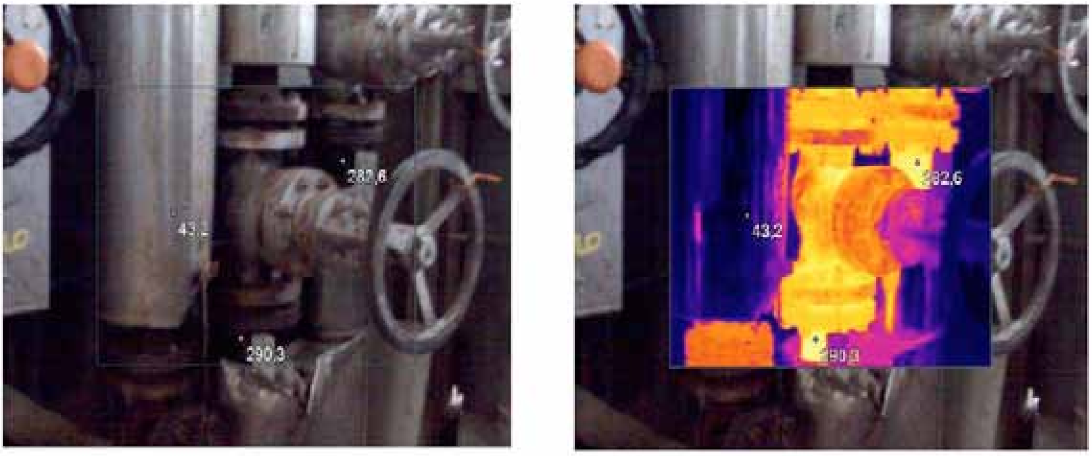

Figure C-2 Regular and thermographic photo of an uninsulated valve

Detected energy loss on each valve:

Internal temperature:	~300 °C
Unnecessary energy loss (8,760 operating hours):	approx. 20,000 kWh / year

Total saving potential for valves:

30 valves x 20,000 kWh/year =	approx. 600,000 kWh/year

Energy efficiency & environment – tanks

Also, 35 storage tanks were found with uninsulated rooftops. The surface of these is about 28 m^2/tank. The temperature of liquids stored inside being 150°C.

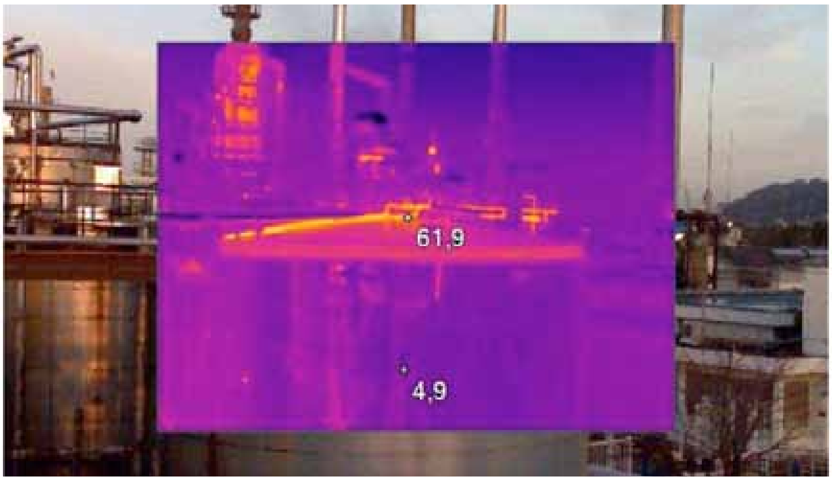

Figure C-3 Thermographic photo of a tank

Saving potential per tank:

Internal temperature:	150 °C
Unnecessary energy loss (8,760 operating hours):	approx. 343 MWh/year

Total saving potential for rooftops:

35 rooftops x 343.3 kWh / year =	approx. 12,000,000 kWh/year

Financial Gains

Investment:

TIPCHECK:	approx. 10,000.- Euro
Insulation instalment and material costs:	approx. 90,000.- Euro
Total investment:	approx. 100,000.- Euro

Realised until today:

Energy cost savings first year	approx. 405,000.- Euro
Energy cost savings following years:	approx. 505,000.- Euro

Payback time:

Time until investment is paid back (energy cost only)	**approx. 2.4 months**

C.2 Refinery tower, Italy

In Italy, one of EiiF Founding Partners performed the following insulation efficiency audit on a refinery tower.

With the maintenance work on the insulation, the choice was made to upgrade the insulation and to improve the fire-safety of the installation. The owner also used a new insulation material with a higher performance.

The result was that by improving their insulation the heat loss via the insulated surfaces could be cut in half. The new system now is not only cost-effective, but also saving energy and therefore reducing CO_2 emissions:

Total annual savings:

Energy savings:	**1,021,958 kWh/year**
Energy costs savings (7 ct/kWh):	**approx. 75,000 Euro/year**
Payback time:	**1-3* years**

*   The new insulation system had to improve the fire protection, which lead to more expensive materials than those that would have been used for energy efficiency only. This higher investment extended the payback time in this example from one to three years.

C.3 Processing plant, Germany

An asphalt boiler of a German company received a new insulation cover. The installed elements consist of:

Tube, ferritic steel, thickness:	5 mm
Width:	1.70 m
Depth:	0.760 m
Height :	26 m
Surface:	127,92 m^2

Other parameters:

Average heat price:	0.033 Euro/kWh
Operating hours:	1,500 hours /year

Project financials:

Insulation investment	12,792 Euro
Energy savings	1,448,500 kWh/year
Energy cost savings	47,800 Euro/year
Payback time	< 3 months

C.4 Chemical plant, the Netherlands

The possible gains from insulating valves and other uninsulated elements of a plant that needed to remain in operation, was investigated by an EiiF Founding Partner. The TIPCHECK engineers measured temperature losses of about 80 objects in 37 different positions along the production line. In this particular case, the client requested to insulate these parts following his own insulation standards. This level is most likely lower than the cost-effective level discussed throughout this study. As such, a higher savings potential could have been achieved if the cost-effective or energy-efficient level of insulation would have been applied. Nevertheless the savings are substantial:

Project characteristics:

Calculated cost of instalment	18,844 EUR
Calculated energy savings:	1,530,000 kWh/year
Savings feedback by client:	28,651 Euro/year
Payback time	8 months

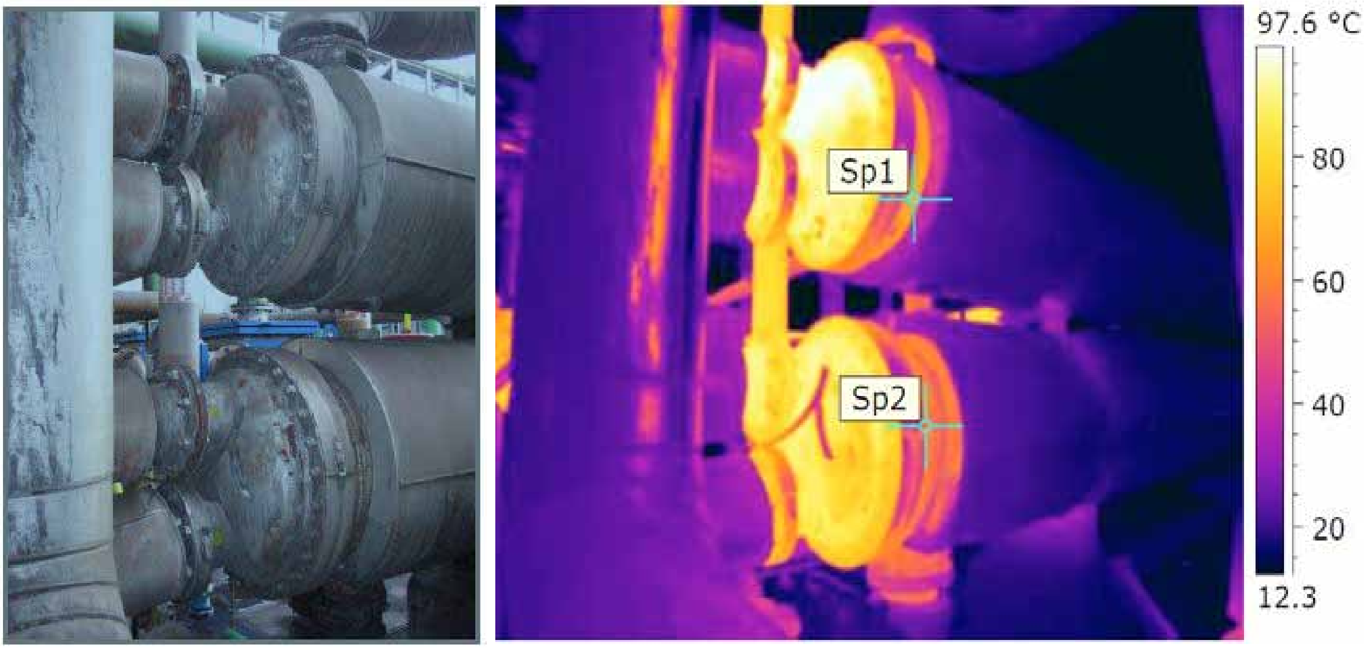

Figure C-4 Regular and thermographic photo showing dangerously high-temperature surfaces

C.5 Machine room, the Netherlands

In this project the heat losses through uninsulated parts was estimated for a steam-distribution net. The audit clearly shows the potential difference between uninsulated and already insulated parts.

Project characteristics:

Calculated cost of instalment:	32,880 EUR
Calculated energy savings on 200 valves	1,280,000 kWh/year
Calculated energy cost savings on 200 valves:	33,530 Euro/year
Payback time	**approx. 1 year**

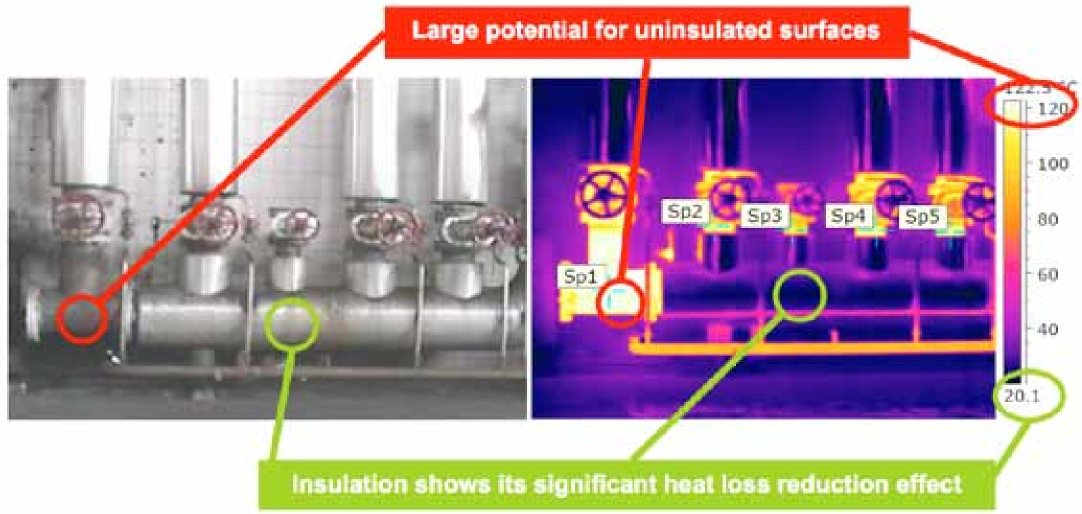

Figure C-5 Regular and thermographic photo showing high-temperature surfaces

C.6 Refinery, Belgium

Engineers from an EiiF Founding Partner company were asked to perform an inspection on a refinery in Belgium. They reviewed the state of the existing insulation system and measured the heat loss over uninsulated parts. With all insulation works executed, roughly 5,000 GJ of energy could be saved every year. This equals to about 325 tCO_2, the average yearly emission of 90 private cars.

Calculated annual saving potential (8,760 operating hours):

Energy savings potential	**4,930 GJ/year 1,370,00 kWh/ year**
- Steam vessels	1,046 GJ/year
- Steam vessel room	58 GJ/year
- Steam vessel – front	124 GJ/year
- Preparation room	467 GJ/year
- Vessel	645 GJ/year
- Refinery room	687 GJ/year
- Extraction room	1,314 GJ/year
- Drums	589 GJ/year
Energy costs savings potential	**36,640 Euro/year**

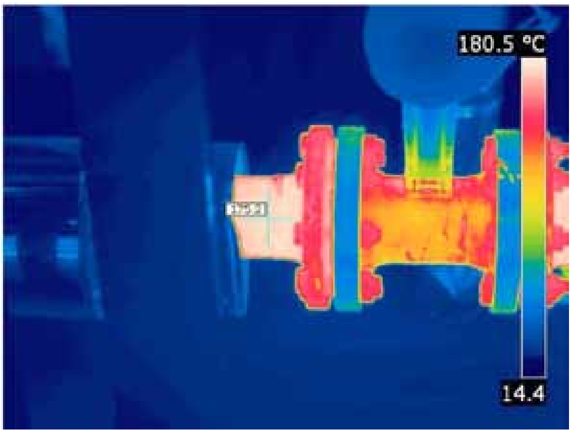

Figure C-6 Regular and thermographic photo showing high-temperature surfaces

C.7 Processing line, The Netherlands

For a processing plant in The Netherlands, insulation engineers were asked to investigate the saving potential of applying, adjusting or improving thermal insulation on valves, flanges and steam pipes in a particular part of the plant. Aside from the heat loss potential, the engineers identified severe risks to personnel safety that the customer was not aware of.

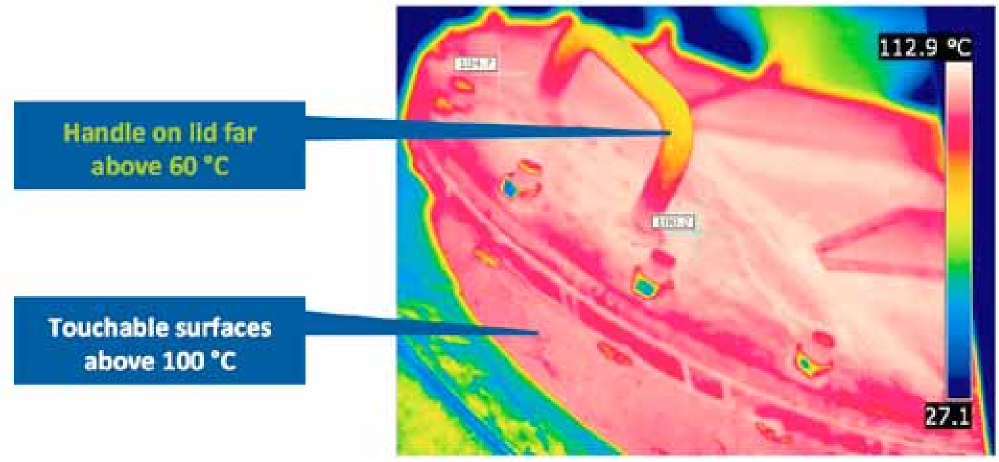

Figure C-7 Regular and thermographic photo showing dangerously high-temperature surfaces

With a run-time of 6,800 hours per year, the calculated saving potential amounted up to about 118,400 m^3 gas equivalent to 885,000 kWh/year. At the clients cost of 0.20 Euro/m^3, this sums up to about 23,700 Euro.

Availability	6,800 h
Energy Savings potential:	**885,000 kWh/year**
Energy cost savings potential:	**23,700 Euro/year**

C.8 Condensation on uninsulated parts

In applications with temperatures below the ambient level insulation has additional demands besides limiting the loss of energy. Below are some examples of cases where several problems occured. These problems were caused by either missing insulation on some parts, insufficient insulation (causing dew point problems) or damaged vapour barriers and/or insulation.

Figure C-8 Pump breaks down

Figure C-9 Valve can no longer be operated

Water vapour is always present in the air. When this vapour comes close to colder surfaces it condensates. This condensation could happen either on uninsulated parts, or inside the insulation layer. A good vapour barrier outside the insulation layer is therefore important.

If condensation is allowed to happen, the water (or ice) will:

- Increase energy losses
  - Water has a 20x higher thermal conductivity than air
  - Ice has a 100x higher thermal conductivity than air
- Cause damage to the insulation material
- Cause corrosion to pipes, vessels & cladding
- Cause structural problems for the installation (due to the extra weight)
- Cause inoperable valves, engines, pumps (ice build-up)
- Cause electrical shortcuts, make control panels brake down

Cold insulations have in general a limited life expectancy: They are unstable systems, which for physical reasons react sensitively to damages. They must be maintained regularly, which includes a routine check of seals and interruptions. This is needed not only to save decent volumes of energy but also to keep industrial processes running.

Figure C-10 Control panel needed to be protected with plastic sheeting from the dripping condensation water. Extensive ice building on pipes and valves

Figure C-11 Broken vapour barriers and insufficient insulation caused ice to form around these pipes causing both process control problems and structural problems

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In 2007, EU leaders endorsed a set of ambitious climate and energy targets to be met by the year 2020. These EU ambitions are known as the 20-20-20 targets.

In this policy context, there is significant attention on measures that reduce energy demand and mitigate CO_2 emissions in all sectors of the economy such as the built environment, transport and industry.

From its experience, the European industrial insulation Foundation (EiiF) is convinced that there is a significant potential for energy savings and CO_2 mitigation by improving thermal insulation in industrial installations. This potential is currently untapped despite being cost-effective to implement. With energy and CO_2 prices likely to rise, this potential is probably growing. Against this background, EiiF commissioned Ecofys to identify the Energy and CO_2 savings potential of industrial insulation in EU27.

The **European Industrial Insulation Foundation** (EiiF) is a European non-profit foundation registered in Switzerland. It has been set up to promote and establish the use of industrial insulation as a widely understood and accepted means of achieving sustainability.

Since its foundation EiiF has established itself as a resource for industries that need to reduce CO_2 emissions and save energy.

Established in 1984 with the vision of achieving "sustainable energy for everyone", **Ecofys** has become the leading expert in renewable energy, energy & carbon efficiency, energy systems & markets as well as energy & climate policies. The unique synergy between those areas of expertise is the key to its success. Ecofys creates smart, effective, practical and sustainable solutions for and with public and corporate clients all over the world. With offices in the Netherlands, Germany, the United Kingdom, China and the US, Ecofys employs over 250 experts dedicated to solving energy and climate challenges.

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