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Energy Efficiency in Bulk Materials Handling

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Climate protection as the only argument does not seem sufficient for the partly highly expensive investment in energy efficient technologies. But due to increasing energy costs, energy efficient equipment gets more and more attractive. Especially the bulk materials handling industry still has an enormous potential to save energy and costs as well.

The topic of energy efficiency is very popular today, not least due to the recently concluded United Nations Climate Change Conference in Copenhagen. Increasing energy costs and the debate of the climatic change with its consequences are the nutrient medium for this development also in the industrial sector. This is the background of this article which deals with the question which potential could become useable in using an energy efficient arrangement of processes and machines.

1 The change of the world climate – Origins and Impacts

In the end of 2009 the 15th United Nations Climate Change Conference in Copenhagen, Denmark, caused a sensation in the world press. It is the second step after the conference of Kyoto, Japan, to confront the preceding climatic change and its consequences on international-law level. The aim for the industrial and commercial sector has to be to combine a reasonable and therefore saving input of resources with economical aims.

Climatic change means the continuing increase of the average earth temperature. In the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2007, six different scenarios of the future warming of the climate system are analysed. In the Best-case-Scenario (B1-Scenariao) the average temperature increases of 1.8°C till the end of the century whereas the Worst-case-Scenario (A1F1-Scenario) predicts an average warming of 4°C [1]. If we believe the climate experts, such a dramatic increase of the average temperature will lead to rising sea levels, famines, a lacking of freshwater supply, a pejoration of air quality and irreversible impacts of the ecosystem [2].

To confront these disastrous effects for mankind, the nations agreed for the first time on binding targets for greenhouse gas emissions at the 3rd UNCCC in Kyoto in 1997 and fixed them in the often quoted Kyoto Protocol. In the Protocol, the climatic change is finally established as a global challenge on a political level and the greenhouse gas carbon dioxide is combated as the biggest "climate killer" which is influenceable by mankind. The agreement entered into force in the beginning of 2005 and includes now 182 nations as completely valid parties. The target agreed upon was an average reduction of 5.2 percent from the 1990 levels in the first commitment period between 2008 and 2012 [3]. The 15th UNCCC in Copenhagen 2009 aimed to agree to a new international framework for climate change mitigation beyond 2012. Even if this was not reached, the negotiators of the participant parties agreed to reduce the greenhouse gas emissions to keep any temperature increases to below 2°C compared to preindustrial levels [4].

But the required reduction of the international carbon dioxide emissions is contrary to the tendency of the last decades (see Fig. 1). Since the beginning of the industrialisation, the carbon dioxide percentage in the atmosphere has increased significantly, mainly during the last 50 years. This shows the importance of the gist of the 4th UN-climate report that an increase of the concentration of carbon dioxide in earth atmosphere contributes directly to global warming. It is here where the topic of energy consumption comes into play. Most of our energy resources are based upon fossil energy sources, which most important component again is carbon. That means that responsible and efficient energy consumption is the most important contribute to climate protection!

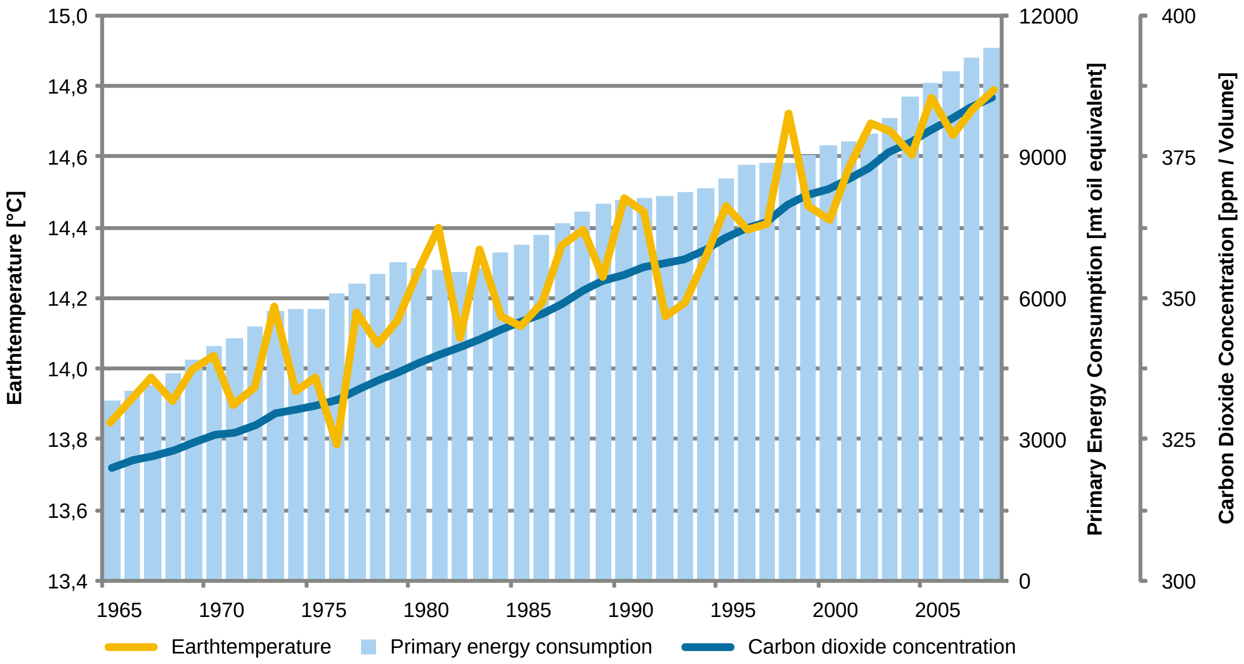

Fig. 1: Global Temperature [5], Primary energy consumption [6] and Carbon dioxide concentration [7] since 1965

2 Cost Savings by efficient use of energy

The climate protection as only argument does not seem sufficient for the partly highly expensive investment in energy efficient technologies. The companies have to sustain themselves in a hard global competition and to operate successfully anyway. But in this context, increasing energy costs lead to rethinking and energy efficient equipment becomes more attractive.

Although the price for crude oil, natural gas and industrial power, has decreased since mid 2008, when the maximum price was reached (see Fig. 2), experts predict a continuing rising tendency for a long-term period: The overwhelming majority of the 200 energy market experts of the Centre for European Economic Research predicted an increase of energy cost for the next five years in August 2009 [10]. According to a publication of the German Federal Environmental Agency, the lion's share of the industrial power consumption is caused to more than 60 percent by electric motors (see Fig. 3). Process heat, lightening or heating use proportionately less power, but should not remain unconsidered when talking about energy efficiency [11].

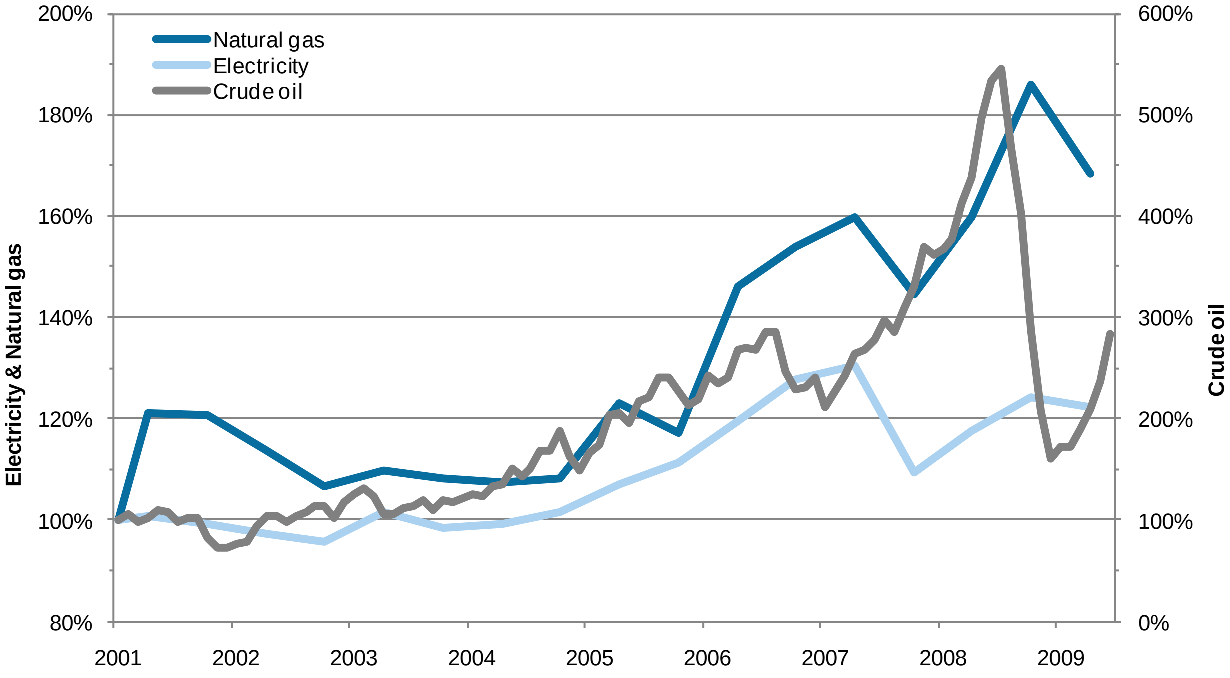

Fig. 2: History of energy costs [8], [9]

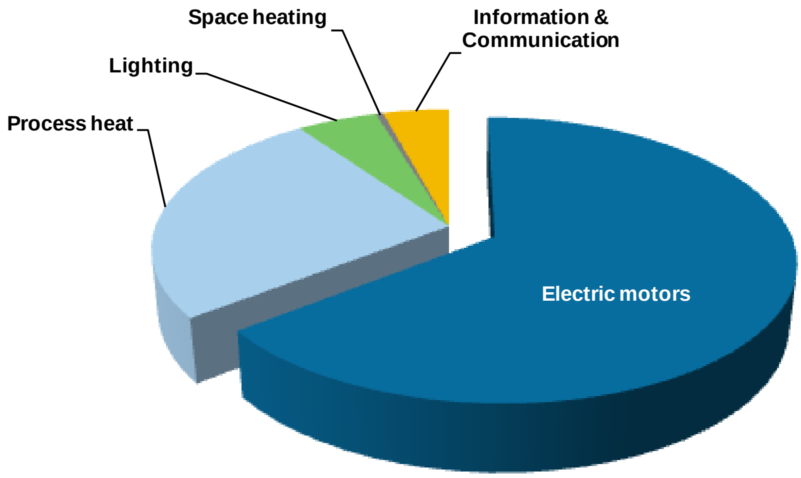

Fig. 3: Electric power consumption in the German industry [11]

Against this background, the Federation of German Industries commissioned a study at McKinsey, in which participated more than 70 companies and organisations in order to evaluate more than 300 levers to avoid greenhouse gas emissions in Germany. The sectors energy, buildings, transport and industry were considered. Thus so-called curves of abatement costs were created (see Fig. 4) which show the available measures. At the same time, these measures are evaluated monetarily, i.e. it is indicated, which costs arise per ton carbon dioxide equivalent. Nearly two thirds of the measures were evaluated as economically, e.g. energy saving motors, speed controllers, waste heat recovery, efficient lightening and optimised heating systems. These measures have together an abatement potential of circa 30 mega tons carbon dioxide equivalent and are thus evaluated as economically reasonable as well as ecologically necessary.

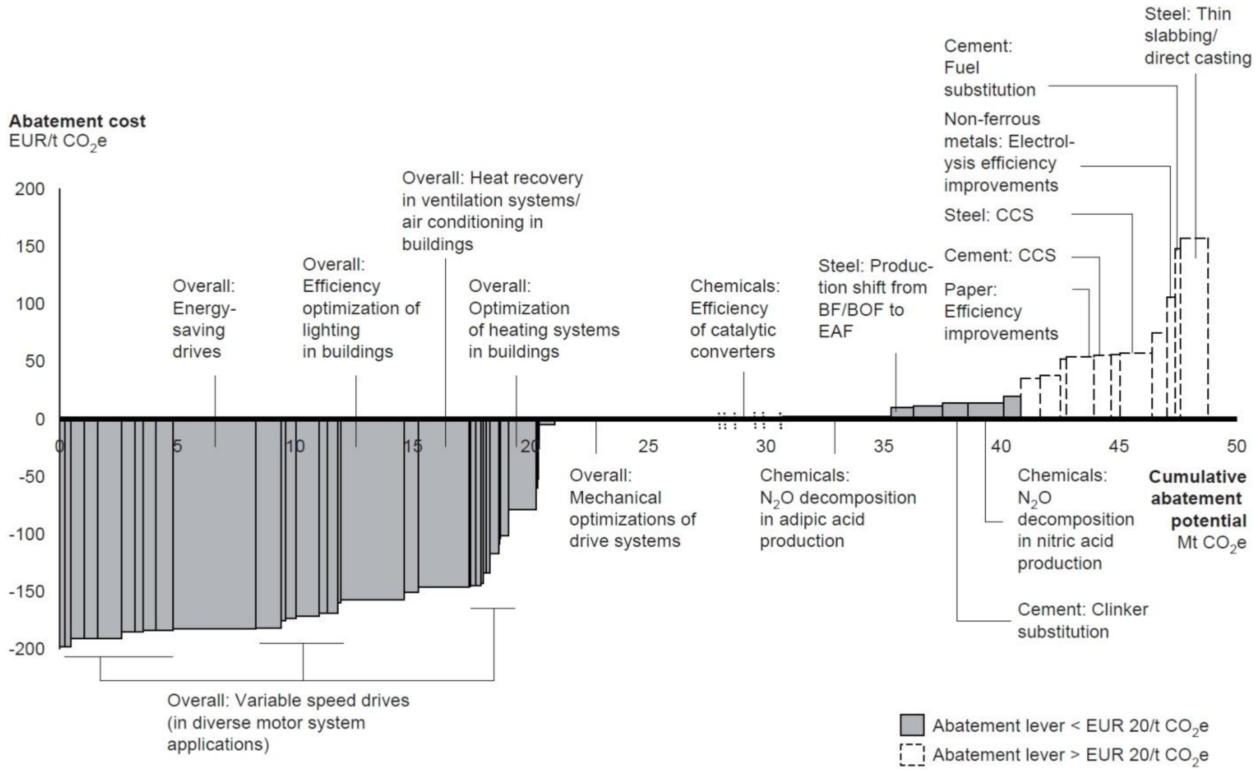

Fig. 4: Abatement costs for the industrial sector in Germany [12]

A brochure of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, published in the middle of 2009, refers to similar ecological and economical results. It introduces e.g. the potentials in cross-section technologies, which are used in all sectors. It is said, that there is a saving potential up to 50 percent for pressurised air systems, which are used in most of the industrial companies. This is shown with the example of an automobile manufacturer, which drove his pressurised air system with a water-cooled rotary screw compressor and four water-cooled piston compressors. An inspection showed that the requirement of pressurised air fluctuated very much. The rework lead to a pressurised air system with air-cooled rotary screw compressor with four machines for the base load and three smaller machines switched on when peak load is reached. A particular pressurised air control technology controls the application of the compressor in dependence of the load. With this method, also the highest operating pressure could be reduced form 8.7 to 7.5 bars. Due to these improvements, the company saves 483 MWh annually and additionally approx. EUR 55,000 a year, because the cooling-water necessity was reduced. Moreover, it is stated that there is an economical saving opportunity of 12 to 15 percent for pumping systems. The payback period for the refitting was in the exemplary case not more than 11 weeks. Altogether there are savings of 20 to 40 percent of the entire industrial energy consumption possible till 2020 for economically reasonable conditions [13].

That the topic of life cycle consideration in context with energy efficient systems plays an important role, is clearly shown by the following number of the Bavarian Environment Agency: For an electric motor with an annual service life of more than 3000 hours, 95 percent of the entire life cycle costs are energy consumption, less than 3 percent are acquisition costs. It is thus too short-sighted to make a decision only based on the acquisition price [14].

3 Efficiency in Bulk Materials Handling

Like all other industrial branches, the bulk materials handling industry still has an enormous potential to save energy and costs as well. As in many industrial branches, in bulk materials handling most of the energy is consumed by electric motors. In the different conveyors they make the transport of the good possible either directly driving mechanical elements or indirectly in using a medium to be pumped, e.g. air. If the area of the conveyors is considered more closely, different starting points can be identified for saving energy. The selected conveying principle very often determines the demand of power. Machines with only a little friction between bulk material and conveying element require much less energy than others. Because of ancillary conditions in hygiene, environment- or explosion protection, closed system types are very often required today for many conveying tasks. A higher friction and, thus, an increased energy demand cannot be avoided with these machines. But nevertheless these machines can be optimised with regard to their energy requirement by appropriate and constructive measures. The drives can be energetically optimised, e.g., in using frequency controlled, efficient motors, low-loss transmission-units and an intelligent control. It is important to consider the interaction of the entire conveyor chain, besides the individual conveyor elements. Capable conveyor lines fulfil many transport tasks more quickly, leading to a reduced runtime of the machines and, thus, reduced consumption. Moreover, the specific energy requirement per handled tonne decreases very often with machines of high capacity.

4 Potentials of Belt Conveyors

The decision for a certain kind of transport system is a preliminary decision for or against an energy efficient and environmentally protecting transport of goods. An example of the extractive industry makes this clear. The extractive industry today is dependent on transporting big quantities of bulk materials to low costs. It is necessary, to transport the good from the decomposition place to a storage place, to a concentration or converting plant. The standard solution for this task is today often the application of dumpers, but the application of a belt conveyor system should always be considered as an alternative solution. Both competing systems have to be compared with regard to the applicability, the financing and the running costs when developing new projects. Because of the high fuel prices and the long delivery times of the dumpers, which are highly demanded, belt conveyor systems become more and more attractive. Compared to dumpers with regard to personal and operating costs, belt conveyor systems have enormous advantages [15]. That the belt conveyor system has also ecological advantages is shown in a case-study by *Zamorano* [16], which provides a comparison between a dumper and a belt conveyor system with regard to the carbon dioxide emission for two different conveyor lines. In the first case (see Table 1), an entire quantity of 60 million tonnes of ore a year have to be transported from a decomposition area to a processing plant, which is 5 kilometers away. The capabilities as well as the fuel requirement of the dumper with a loading capacity of 190 tonnes each were calculated based on information given by the company Caterpillar; the electricity generation is based on the consumption of natural gas.

Table 1: Carbon dioxide emissions, case study 1 [16]

	Truck		Belt conveyor
Availability	80%	Availability	90%
Operating Hours	7,008 hr	Operating Hours	6,570 hr
Truck Cycle Time	0.35 hr		
Tons Transported per truck	543 t/hr		
Number of trucks required	15.8		
Fuel Consumption per truck	140 l/hr	Absorbed power	5780 kW
CO_2-Emissions per truck	372.4 kg/hr	Energy used	37,975 MWhr
Total CO_2-Emissions	**41,113 t**	**Total CO_2-Emissions**	**17,089 t**

The sample calculation shows, that it is possible to save an annual quantity of 24024 tons of carbon dioxide, if belt systems are used instead of dumpers. This saving still increases, if the conveyor line is lengthened and a difference in altitude has to be managed. This clarifies example two: A quantity of 36 million tonnes of ore is transported over a distance of 8.4 kilometers from the breaker to a processing plant which is situated 700 meters higher than the breaker. The dumpers have a loading capacity of 300 tonnes each; the electricity generation is based again on the consumption of natural gas. As shown in Table 2, the belt conveyor system helps to save 67 676 tonnes of carbon dioxide a year. These savings are hard cash due to the determined commerce of carbon dioxide certificates decided in the Kyoto Protocol.

Table 2: Carbon dioxide emissions, case study 2 [16]

	Truck		Belt conveyor
Availability	80%	Availability	90%
Operating Hours	7,008 hr	Operating Hours	6,570 hr
Truck Cycle Time	1.25 hr		
Tons Transported per truck	240 t/hr		
Number of trucks required	21.4		
Fuel Consumption per truck	300 l/hr	Absorbed power	17,550 kW
CO_2-Emissions per truck	798.0 kg/hr	Energy used	115,304 MWhr
Total CO_2-Emissions	**119,563 t**	**Total CO_2-Emissions**	**51,887 t**

Though the belt conveyor has great advantages as shown before confronted with a discontinuous transport, and is considered as very energy efficient for transporting big quantities over a longer distance, improvement potential is possible. When such equipment is designed, the motion resistance flow into the calculation of the drive capacity. A consideration of the percentage shares of the motion resistances show therefore also the possible saving potential.

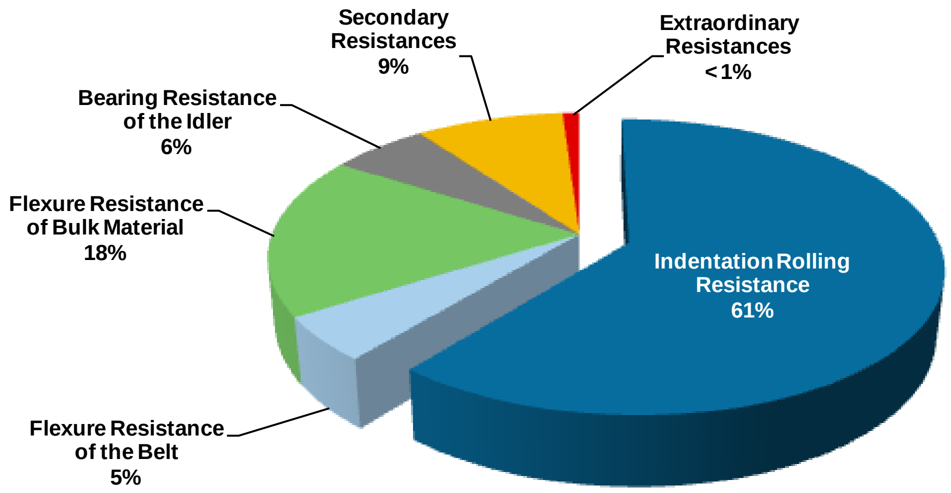

Fig. 5: Percental distribution of motion resistances of a long-distance horizontal belt conveyor [17]

Such a distribution of the motion resistances was worked out by *Hager* and *Hintz* [17]. Their results (see Fig. 5) show that 61 percent of the entire resistance of horizontally lead systems results from the indentation rolling resistance. This value is influenced significantly by the condition and quality of the belt [18]. Due to the constructive design of the system, it is possible to reduce the secondary resistances which result, e.g., from the supply and releasing of the bulk materials or from the chutes. The bearing resistance of the idler can also be reduced, if smooth-running or particularly energy efficient belt idlers are chosen [19]. According to manufacturer's declaration, a total energy saving of 15 percent can be reached, if a concerted optimisation of belt conveyor systems regarding their energy demand, e.g. by using energy saving belts and smooth-running idlers, is put into practice.

5 Consumption of Ship Unloaders

Due to the development of a number of studies in the field of port handling during the last years, the Institute for Materials Handling Material Flow Logistics (**fml**) has had the opportunity to visit many port companies and interview them in regard to the used conveyor systems and their energy requirements. It was confirmed, that – as we assumed before – the unloading equipment caused by far the main part of the energy consumption. As the greatest single consumer, the process of ship unloading, thus, offers also the greatest saving potential in the energy balance of the company, and that's why it seems reasonable to consider this process more precisely. This is shown at an example of a handling company for agricultural products. Different factors play a part in the choice of the kind of unloading equipment. Companies often need unloading machines which are able to carry very different conveying good, free flowing goods like grain as well as cohesive goods like grist and other mill afterproducts. Moreover, the legal requirements with regard to negative environmental impacts caused by dust and noise have been tightened in many countries. Other aspects are capability, reliability, energy consumption and of course the purchase price of the machines. The analysis of the life cycle costs suits well to show, how the different qualities of the machines for example the energy consumption or the amount of maintenance under certain conditions, determined by discount rates or current prices, influence the entire costs. It is therefore possible to estimate, whether the investment in energy efficient conveying principles pays off. To calculate the life cycle costs exemplarily the three typical kinds of unloaders as screw-, chain- and pneumatic type are picked out. The calculation bases on the data showed in Table 3.

Table 3: Data of ship unloaders

	Pneumatic	Screw Type	Chain Type
Acquisition Costs	1,700,000 €	2,600,000 €	2,500,000 €
Average Capacity	60 %	75 %	80 %
Power consumption per ton	1.4 kWh/t	0.9 kWh/t	0.4 kWh/t
Maintenance costs (first year)	70,000 €	56,000 €	53,000 €

A handling facility with an annual handling volume of 1 million tonnes of grain and one unloader (capacity 600 t/h; reliability 90 percent) is considered. Every 10 years a heavy maintenance is performed, which leads to costs of EUR 300000. The unloader is electrically operated; the electricity costs are EUR 0.10 per kilowatt-hour. The averaged number of employees per day is 2.25, whose hourly wage is EUR 20. The operation time per day is 22 hours. Demurrage and charter costs are not considered.

The calculated life cycle costs are shown in Fig. 6. With approximate identical initial investment costs a clear difference in the entire costs arise over a period of 30 years. The higher costs of pneumatic unloaders are not only caused by the higher power requirement of those machines, but result also from the less averaged capacity and the therefore longer unloading time. A comparison of the similar effective unloaders of screw and chain type shows the cost benefit, caused by the lower power requirement. This benefit would be even more obvious, if you take the escalation of energy costs of the last few years as a basis.

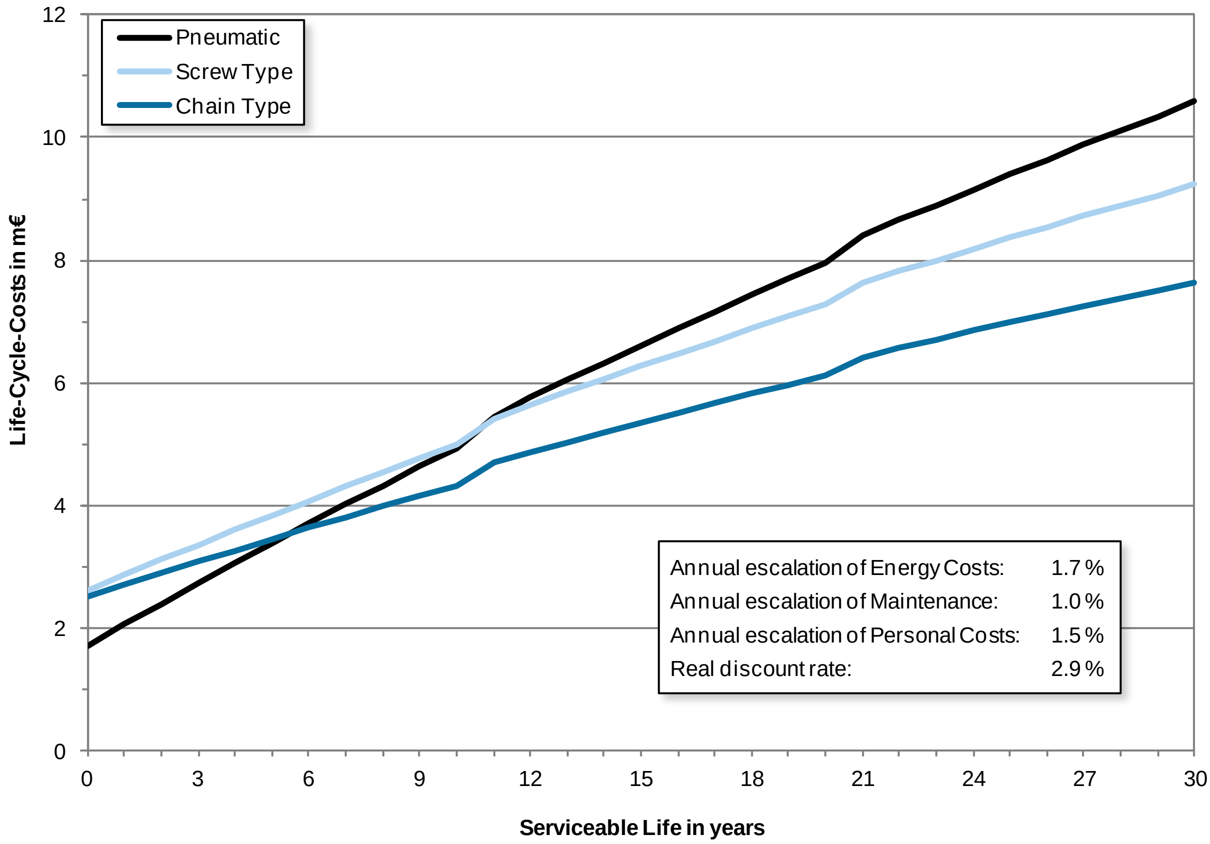

Fig. 6: Life Cycle Costs of different kinds of ship unloaders

6 Summary

The factor energy efficiency will gain significance in future as a criterion for the acquisition and therefore as a target value in the phase of development of technical systems as well as in the bulk materials handling technique. This tendency will be determined at one hand due to increasing energy costs, which will focus more the life cycle costs of machines and systems when decisions of investment are made. At the other hand, the general climate debate encourages the ecological thinking in the context of sustainable economic activities. The ecological action, i.e. the economical handling of resources as electric current, which will become also more attractive financially in future as showed above, offers two advantages from the entrepreneur's point of view: The ecological necessity is now also economically reasonable.

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