Simulation of Bulk Materials Ship Unloading with a View to Energy Efficiency

W. A. Günthner, M. Mirlach, S. Rakitsch

Institute for Materials Handling, Material Flow, Logistics (fml), Technische Universität München

rakitsch@fml.mw.tum.de

Abstract

The topic of energy efficiency is a very popular topic now. Increasing energy costs and the debate of the climatic change with its consequences are the nutrient medium for this development. This is the background of this article which deals with the question how potentials concerning the energy consumption as well as the costs can become useable in the field of bulk materials ship unloading. Besides the use of energy efficient technologies in the unloading terminals, the strategy of unloading a ship shall play a decisive role here. As tool to optimize an unloading strategy a simulation program is used, which makes it possible to simulate a complete ship unloading process in a little while considering various boundary conditions. In this way an optimal strategy can be found for a certain unloading process before a ship enters the port and considering the up-to-date conditions. A fast, energy efficient and cost saving unloading process is thus possible.

1 THE CLIMATE CHANGE AND ITS IMPACTS

The change of our world climate is a favoured topic of conversation at present and is gladly picked up by the media not least due to the 15th United Nations Climate Change Conference in Copenhagen last year. In this context the climate change is synonymous with the continuing increase of the averaged earth temperature. To point these changes in the climate out, the Intergovernmental Panel on Climate Change (IPCC) works out the so-called UN-climate reports. In the Fourth Assessment Report, published 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) even 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 melting polar ice caps, rising sea levels, famines caused by bad harvests, a lacking of freshwater supply, a pejoration of air quality and irreversible impacts on the ecosystem. The costs caused by such extreme climatic changes can add up to 20 % of the global economics [2].

To confront these disastrous effects for mankind there are only the results of the 3rd United Nations Climate Change Conference in Kyoto in 1997, which are written down in the often quoted Kyoto Protocol, existing under international law today. For the first time binding target values for the emission of greenhouse gases were defined therein. Two articles are especially worth mentioning: On the one hand the target of an averaged reducing of the greenhouse gas emissions by 5.2 % from the 1990 levels in the first commitment period between 2008 and 2012 was fixed. On the other hand the opportunity was provided for the nations to trade the "packages" of carbon dioxide emissions, which are defined in certificates [3]. For this reason a reducing of carbon dioxide emissions can pay off in hard cash [4]!

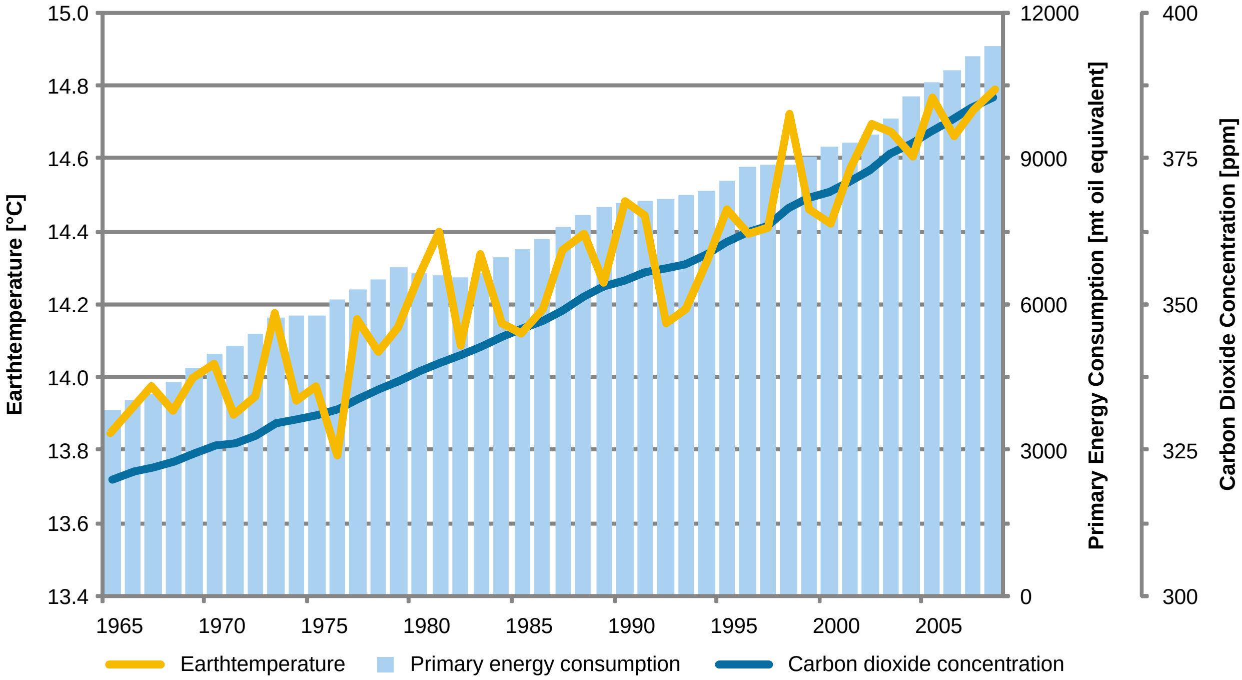

Fig. 1: **Global Temperature [5], Primary energy consumption [6] and Carbon dioxide concentration [7] since 1965**

But the required reduction of the international carbon dioxide emissions in this regard 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 the anthropogenic carbon dioxide in earth atmosphere contributes directly to global warming [1]. It is at this point 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 and is also the most important interest of mankind!

2 ENERGY EFFICIENCY AS COMPETITIVE ADVANTAGE

Thus the companies in the port environment have to sustain themselves in a hard global competition and operate successfully, increasing energy costs lead to rethinking in this context. Against this background, energy efficient equipment becomes more attractive from the economic point of view. Although the price for crude oil, as well as for 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 [8].

Electric motors drive in large part, direct or indirect by hydraulic systems, the ship unloaders and thus are the main energy consumer, as also in other industrial branches. A publication of the German Federal Environmental Agency which looked into the energy consumption of the German industry also documents this: The lion’s share of the industrial power consumption is caused to more than 60 % by electric motors. Process heat, lightening or heating use proportionately less power, but should not remain unconsidered when talking about energy efficiency [11].

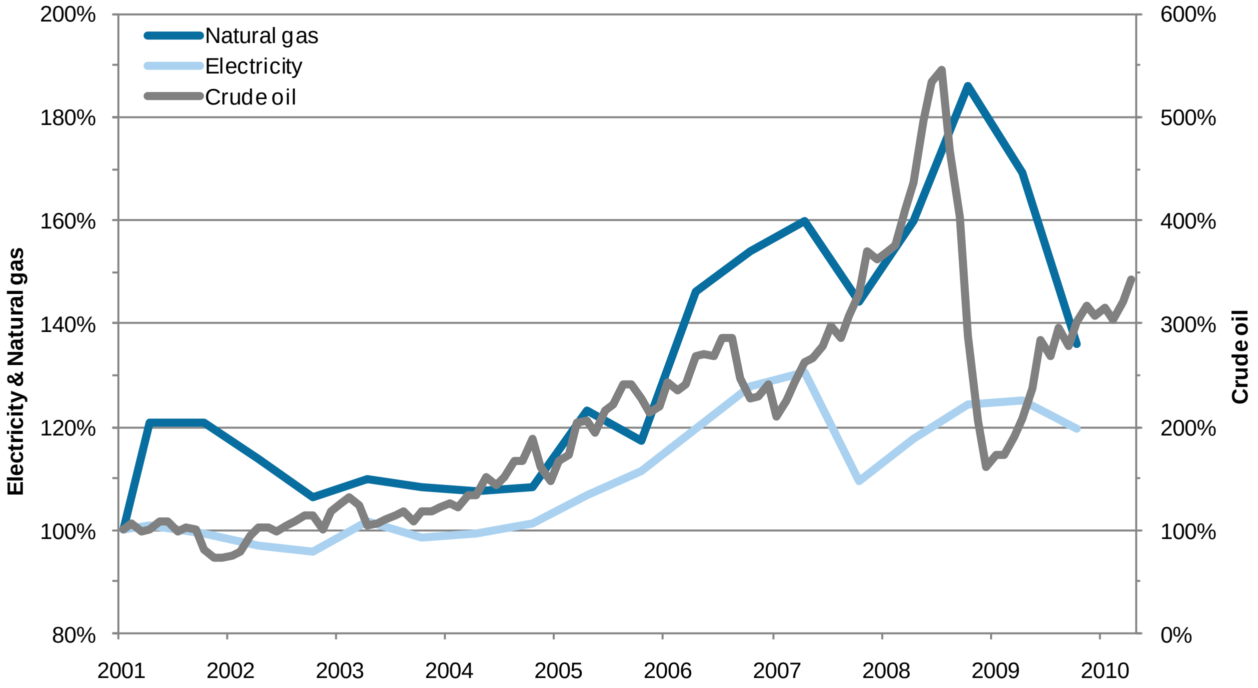

Fig. 2: History of energy costs [9], [10]

That the topic of Life Cycle Consideration in context with energy efficient systems plays an important role, is clearly showed by the following number of the Bavarian Environment Agency: If you use an electric motor with an annual service life of more than 3,000 hours, 95 % of the entire costs during the durability fall upon energy consumption, less than 3 % upon acquisition. It is therefore too short-sighted to make a decision only dependent on the acquisition price [12], as just the energy consumption of electric drives can be optimized, e.g., in using frequency controlled efficient motors, low-loss transmission-units and an intelligent control. Savings up to 40 % are possible here [13]. 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, which can lead to a reduced runtime of the machines and therefore to a reduced consumption. Another possibility to reduce the energy consumption is to use energy optimized components. This can be proved at the example of belt conveyors which are commonly used amongst others as quay conveyors at port sites. Altogether a complete energy saving of 15 % can be reached, if a concerted optimisation of belt conveyor systems regarding their energy demand, for example in using energy saving belts and smooth-running idlers, is put into practice, according to manufacturer's declaration [14]. Summing up considerable energy and therefore also cost savings are possible by operating energy efficient and this leads to a competitive advantage again.

3 ENERGY CONSUMPTION AND SAVINGS IN THE BULK MATERIALS SHIP UNLOADING

This also applies to the bulk material terminals in the world's ports. Various surveys at the Institute for Materials Handling, Material Flow, Logistics in the last years showed that in these companies the ship unloader is of course the biggest single energy consumer. The example of an agribulk unloading terminal possesses percentages of more than one-third for the energy consumption of the ship unloaders (see Fig. 3).

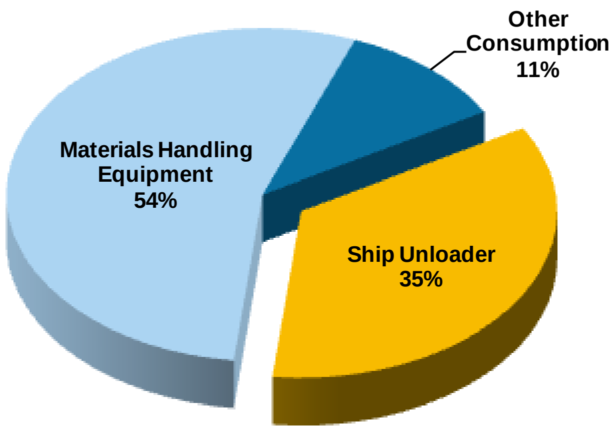

Fig. 3: Breakdown of the Power Consumption of an Import Terminal

The first idea to save energy at the unloading facilities is of course to optimize the single components as described above. Another possibility to save energy is to use the potentials of energy recovery systems. The sinking process of the clamshell of a gantry crane shall be noted as an example at this point. Generally the electric motors of the godet and the closure unit are running generative then; the gained energy is often annihilated in resistors. In feeding back this energy in the power supply system the specific demand of energy per tonne unloaded bulk material can be reduced considerably (see Fig. 4). Depending on the electricity tariffs and the amount of handled bulk material the investment in a energy recovery system can be saved within a short period by reducing the energy consumption.

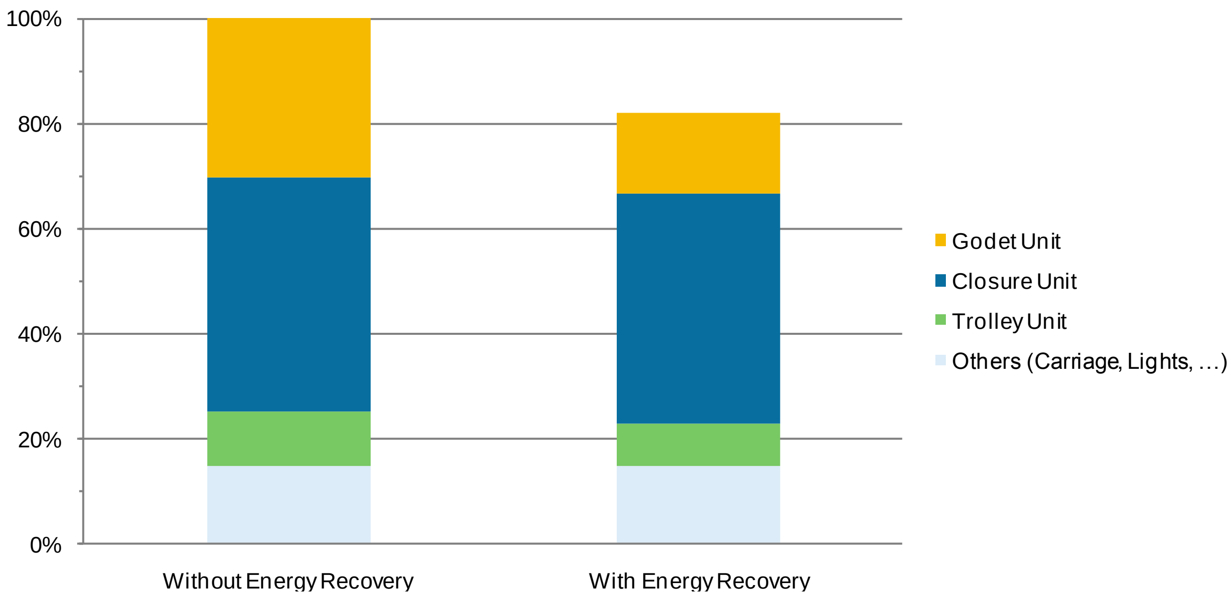

Fig. 4: Breakdown of the Power Consumption of a Gantry Crane with and without Energy Recovery

In addition to the aforementioned possibilities of reducing the energy consumption by the use of energetically optimized systems, also the operating time has certainly a decisive influence on the total energy consumption of ship unloaders and the downstream conveyors, as almost the entire consumption is due to the direct operation. To reduce the ship discharging time, the unloading process must run as efficiently as possible at all phases. That means that breaks, downtimes and phases with a low mass flow must be avoided. To attain this goal for existing and being planned ship unloading facilities, optimal unloading strategies and with it a high average mass flow must be found for various ship types, bulk materials and other boundary conditions. The development of applicable methods and algorithms is a current research project at the Institute for Materials Handling Material Flow Logistics. Simulation is used as an essential tool therefore.

4 SIMULATION OF BULK MATERIALS SHIP UNLOADING

The actual mass flow rate that can be achieved by a specific unloader is, beside of its rated capacity, determined by many factors. The maximum flow rate can only be obtained under an ideal combination of operating conditions, i.e. with defined material properties, optimal accessibility to the cargo, and sufficient afflux (free-flowing or forced) to the inlet. The flow rate that is actually attained can diverge considerably and varies greatly in different stages of the unloading process.

4.1 Determinants

The accessibility of the cargo hold may be a restraining issue. In many cases, the cargo in the peripheral areas of the holds can not be reached, since the movement of the unloader is confined by the dimensions of the hatch opening. If the vessel is wider than the workspace of the unloader, great parts of the cargo on the side opposed to the quay cannot be accessed either. Finally, the unloaders sometimes cannot long to the holds' floor plates if the ship lies very deep at low tide or due to its high draft. For being able to extract also the remaining cargo that cannot be reached directly, different feeding devices such as wheel loaders, bulldozers and excavators are deployed in the holds. These machines move the material to a location from where the unloader can pick it up, or feed it directly into the unloader's inlet. Another aspect that must be considered is the behaviour of the bulk material itself. Under ideal circumstances, the cargo slides and forms conical pits according to the angle of repose. Caused by its self-weight and exposure to vibration or humidity during transport, rigidification or caking can occur, especially at the hold's walls. These regions must be broken up manually or by the use of applicable machinery. Further attention should also be paid to the stresses and deformations that the ship's hull experiences during the unloading process. Longitudinal weight imbalances lead to transverse forces and bending moments that can cause damage to the ship's structure, if they exceed the admissible limits. To guarantee an even load distribution along the vessel, the unloaders need to change holds, even when there is still enough material available. Alternatively, the crew of the ship must conduct ballast operations to compensate the forces. Other factors to be considered are, for example, ebb and flow.

4.2 Unloading strategy

All these influences must be considered when planning a strategy for unloading a certain ship at a certain facility. The unloading strategy is the basis for the dispatching and scheduling of the working personnel, unloaders and feeders. In order to carry out the unloading as efficiently as possible, every available piece of the unloading-machinery must be deployed under the operating conditions that it is best suited for. The unloaders available on site often vary in their dimensions, manoeuvrability and conveying principle (screw or chain conveyor, bucket elevator, pneumatic conveyor or clamshell grab). Hence, each of them is appropriate only to a particular extent for the different sub-tasks and stages of the process. The unloading strategy has to cater to the respective available machinery.

4.3 Planning tool

In this research project, a technique will be developed to provide assistance in planning the unloading procedure. A functional model of a computerized planning tool will be developed (see Fig. 5).

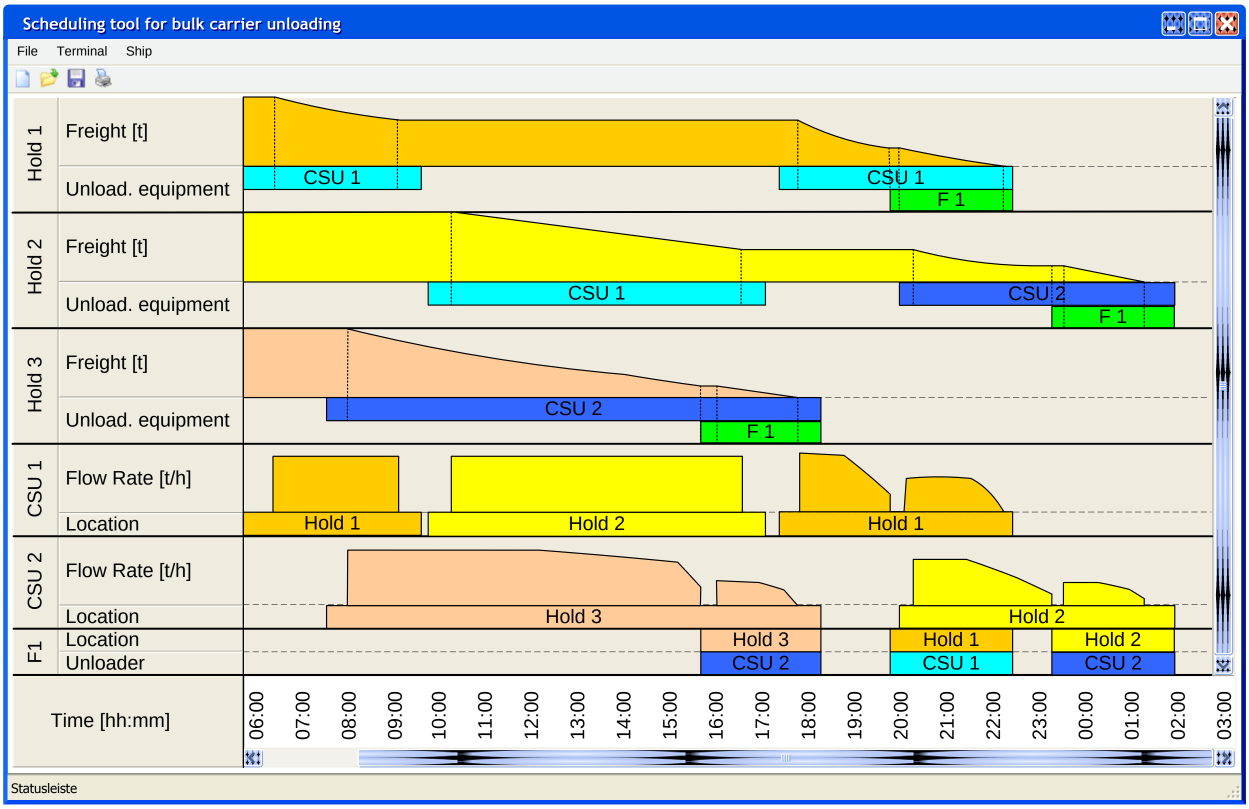

Fig. 5: **Mock-up of the auxiliary tool for planning the unloading procedure (CSU: Continuous ship unloader; F: Feeding device)**

With this tool, the unloaders and feeding devices can dynamically be assigned to the different holds of a ship. The attainable mass flow rate is calculated automatically based on the prevailing conditions. The time needed for moving the unloaders to the holds and for lifting the feeding devices in and out will be taken into account as well. The simultaneous use of multiple feeders and unloaders in the same cargo hold will be possible. In order to determine the mass flow rate that can be achieved, at first the reachable subspace of the hold is determined. Therefore, a geometric model of the unloader and the ship is required. Potential collisions of two unloaders can be detected in this way as well. According to a configurable strategy, a point is selected from the reachable subspace from where cargo is being extracted. The resulting mass flow depends both on the inlet's depth of immersion into the cargo, and on the local material properties. By simulating the cargo's material behavior, the mass distribution in the holds is updated continuously.

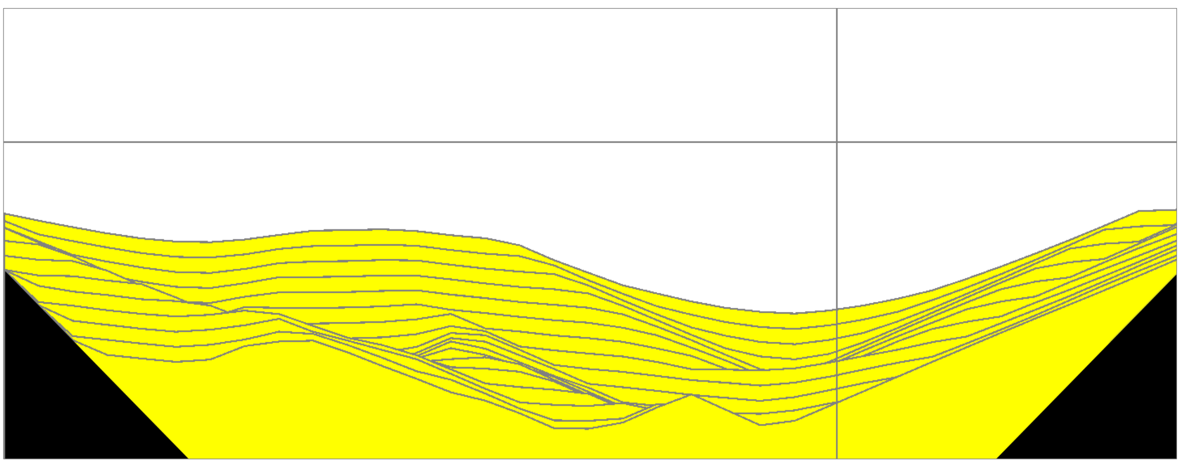

Fig. 6: **Spatial distribution of the cargo in a hold**

The consideration of feeders will also be possible. The feeders take up cargo in a selectable area and move it to a different location. The control of the feeders can be done automatically according to a selectable strategy, semi-automatically or manually. The position of the ship is determined by the cargo weight and by the water level, which is subject to the tides. The weight distribution along the vessel is monitored to detect any exceedance of limits.

4.4 Goals

The techniques that are being developed facilitate the planning of unloading procedures for bulk carriers. Many different types of influences can be examined using a single tool. Different strategies can easily be compared and the effects of modifications can be evaluated instantaneously. In this way, it is possible to make out potential savings of time, cost and energy consumption.

5 CONCLUSIONS

Due to raising energy costs and growing ecological awareness the factor energy efficiency will most likely gain significance as a criterion for the acquisition and operation of technical systems also in the bulk materials handling technique in future. For companies, working in the field of bulk materials ship unloading, it makes therefore sense to fit the dock site with optimized technique like energy recovering systems on the one hand. On the other hand time and therefore costs can be saved by using an optimal unloading strategy to operate them. To optimize the unloading strategy the Institute for Materials Handling Material Flow Logistics is currently developing a method to simulate the unloading procedure of a complete ship. Therewith it is possible then to find an optimized strategy before the ship enters the port and considering all relevant boundary conditions.

6 REFERENCES

[1] Solomon, S.; et. al.: Summary for Policymakers; In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC); Cambridge University Press, Cambridge, UK and New York, USA, 2007.

[2] Stern, N.: The Economics of Climate change – The Stern Review; Cambridge University Press, Cambridge, UK, 2008.

[3] United Nations: Kyoto Protocol to the United Nations Framework Convention on Climate Change; 11th DEC 1997; http://unfccc.int/resource/docs/convkp/kpeng.pdf; 17th DEC 2009.

[4] European Commission: EU Action against climate change. The EU Emissions Trading Scheme; Luxembourg: Office for Official Publications of the European Communities; 2008

[5] Goddard Institute for Space Studies: Global Temperature Anomalies in 0.01 degrees Celsius; http://data.giss.nasa.gov/gistemp/tabledata/GLB.Ts.txt; 18th DEC 2009.

[6] BP p.l.c.: BP Statistical Review of World Energy June 2009; http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2008/STAGING/local_assets/2009_downloads/statistical_review_of_world_energy_full_report_2009.xls; 17th DEC 2009.

[7] Earth System Research Laboratory: Mauna Loa CO2 annual mean data; ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt; 18th DEC 2009.

[8] Centre for European Economic Research (ZEW): Schwerpunkt Energiemarkt - Energiemarktbarometer, Juli/August 2009; ftp://ftp.zew.de/pub/zew-docs/zn/schwerpunkte/ energiemarkt/Energiemarkt0709.pdf; 21st DEC 2009.

[9] European Commission, Eurostat: Electricity & Gas - industrial consumers - half-yearly prices; http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database; 21st DEC 2009.

[10] Organization of the Petroleum Exporting Countries (OPEC): Monthly Oil Market Report; http://www.opec.org/home/Monthly%20Oil%20Market%20Reports/2009/mr122009.htm; 21st DEC 2009.

[11] German Federal Environment Agency (UBA): Stromsparen: weniger Kosten, weniger Kraftwerke, weniger CO_2 Fakten und Argumente für das Handeln auf der Verbraucherseite; http://www.umweltdaten.de/publikationen/fpdf-l/3191.pdf; 21st DEC 2009.

[12] Bavarian Environment Agency: Klima schützen – Kosten senken; 2004; http://www.lfu.bayern.de/luft/fachinformationen/co2_minderung/doc/energieleitfaden.pdf; 22nd DEC 2009.

[13] Nord Drivesystems: Eco-friendly and cost-saving: Energy efficient drives from NORD; In: IEN Europe, Vol. 35 (2009), No. 4, Page 33.

[14] Kropf-Eilers, A.; Overmeyer, L.; Wennekamp, T.: Energy-optimized Conveyor Belts - Development, Test Methods and Field Measurements; In: Bulk Solids Handling, Vol. 29 (2009), No. 1, Pages 24 – 29.