

“Shipping as an opportunity for the reduction of energy consumption and emissions”

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Only in recent years the contribution of shipping to worldwide emissions has been critically questioned. Yet in hardly any other economic sector it is as relatively easy as in shipping to achieve immediate massive emission reductions on a worldwide scale with technologies available already today. It is not intended to revive nostalgic-outdated approaches (“Windjammer”); instead a re-invention on the basis of the actual, technological possibilities is herewith proposed.

The oil price will not any more decrease substantially and sustainable energies for the actual transport needs will become more and more competitive. Scientists (Prof. N. Zajonc, Bremen) say: a sustainable approach in shipping is necessary; engineers (Dipl.Ing.P.Schenzle, Hamburg) say: it is feasible; economists (Dipl.Vw. H.Schaale, Hamburg) say: it becomes more and more economically accessible.

The future vessel will be a "system vessel", which uses state-of-the-art technology and will have the "zero-emission-vessel" as the ultimate target. On the basis of wind power assisted by conventional auxiliary propulsion solar and other energy technologies will be applied as soon as these are implemented. The result will be a modern bulk vessel respectively tanker, which will soon overtake their conventional competition especially on intercontinental routes in both reductions: in bunkers (energy) consumption and in emissions.

Chapter 1: Introduction

During the last one hundred years international shipping has suffered a similar epoch-making and incisive transformation as other sectors of the economy, which meanwhile is termed as "developed" and has prevailed worldwide. The milestones of this transformation have been mainly the substitution of the venerable sail by motor propulsion, the emergence of special vessel types for the transport of the commodities demanded by modern economy, the increase in size of some of these vessel types and the consequences resulting from specialization and size for the port economy and the hinterland. These trends have led to the development of transport and logistic chains, which meanwhile extend almost everywhere and in which the ship is only an integral component among many others, which has to fit in as smoothly as possible (Schaale, H., 2003).

The era of cheap energy with its excessive use are terminated (IEA 2007: Fact Sheet Oil). The consequences of this excessive use have clearly shown itself in the last decades and are becoming under the catchword “climate change” an action parameter for the international, increasingly globalized, policy. The causality between consumption of energy and ecologic damages is not questioned any more by leading sections of the scientific community and compels the politicians more and more to act accordingly. In spite of the - according to the opinion of many - delayed implementation of measures recognized since long as inevitable for the reduction of the consequences of the climate change, the emission certificates trade has been established since 2005. It is increasingly considered as a system-adequate instrument to prod the economy to developments, which can limit the damaging consequences to the climate of the economic activities and which maybe even reduce them.

Only in recent years has shipping also come under such scrutiny. Though it is by far the most environmentally friendly means of transport, it is mainly operated with an energy resource, which –when ashore - has to be disposed off as an especially poisonous waste, namely heavy

fuel oil. Its effects offshore are difficult to record and have till recently hardly been acknowledged, let alone seen as a problem.

The principal topic of this paper focuses on the effects of the main fuel resource of shipping, the heavy fuel oils (HFO, MFO). As with any combustion process an amount of more or less poisonous substances are generated - carbon dioxide, sulphur dioxide, nitrogen oxide - and the combustion residues together with the air generate aerosols. These originate on one side the well known emissions hazardous to climate and detrimental to health and on the other side a more intense formation of clouds, which are claimed to have partially cooling effects on the climate (Lauer e.a., 2007).

Moreover, the heavy fuel oil before combustion must be cleaned from sediments and these must be disposed properly, which is still (too) often done by simple dumping at sea. These highly poisonous residues as well as the above mentioned gaseous emissions dissolved in the sea affect directly the life cycles of many marine creatures, thus damaging the highly interlinked biosphere "ocean".

Actually international efforts for cleaning the environment have begun in shipping circles relatively early (1922 USA, 1934 League of Nations, 1950 IMCO (forerunner of IMO). In those days however they targeted mainly the - visible - oil pollution by ships. Only in 1973 with the „International Convention for the Prevention of Pollution from Ships 1973“ - known as MARPOL - the air pollution by ships was increasingly acknowledged. In the middle of the decade of the 1980ies preparatory works for the complex "air pollution" were started, but only in the MARPOL-Annex VI of 1997 this special issue was tackled in a structured way; its regulations however came into effect only on May 9th, 2005 (IMO 2008).

This long time period alone reflects the difficulties to identify this problem, to assess it and finally to agree to adequate measures. That still doesn't mean that they are also implemented which, considering the - frequently vested - economic interests of the interested parties (shipowners, shippers) is somewhat understandable. After all, vessels are long-term investments, which must amortize themselves; the new regulations imply new, expensive technologies and, above all, the ensuing costs are unpopular - the envisaged sulphur-reduced, "environmentally friendly" fuels (MDO) are almost twice as expensive as the up to now mostly used heavy fuel oil (HFO, MFO).

In the distillation process of crude in especially older refineries there are produced petrol, Diesel fuel, etc. and - mostly with strong sulphur content - heavy fuel oil as a „residual product“. In modern refineries the applied process allows to greatly reduce the share of heavy fuel oil - in Germany it is only marginally produced. However, the demand for heavy fuel oil increases considerably in the ascending threshold countries (BRIC) - a question of price (Wikipedia 2008, "heavy fuel oil"). This also shows that these threshold countries are not prepared to restrict their economic perspectives in favour of a greater environment friendliness of their essential shipping activities.

New, first-time studies (Bojanowski, A. (2007), (Lauer e.a., 2007) in the USA and Germany come to alarming results concerning the effects of the vessels' exhaust fumes on the state of health of coastal populations. Especially affected are Western Europe and the Far East, since the shipping lanes there run along the coasts. The aerosols and gaseous emissions drift with the prevailing west winds upcountry and blend with the emissions generated on land. Their effects are significantly detectable in port cities, along large rivers and even far into the hinterland (Corbett e.a. 2007).

Chapter 2: The Challenge

More than 80% of the worldwide exchange of goods (according to volume) is transported by vessels. Insofar it stands to reason that, in spite of all their already existing environmental compatibility (= relatively small energy input per transported unit), they represent a gigantic saving potential for energy and thus for emissions. One can only muse, why this potential has become an issue only so late in contrast to the arguments concerning the land and air traffic.

Emissions are the result of the application of energy in the most diverse economic activities. In the case of shipping, since more than a century vessels are operated with fossil energy resources - at first with coal, then oil – for fuelling the ship's propulsion. Cheap oil as well as simple and comfortable engine handling have since had as a consequence, that practically all commercial shipping is nowadays operated with oil.

Considering the cheap fuel there have hardly been made any serious attempts to challenge its dominance, with exception of the nuclear technology. However, it quickly became clear, that the promises of allegedly inexhaustible nuclear fuel could not be fulfilled in face of the magnitude of the technological and economic risks, which after all only government institutions (navies) could shoulder. An economic operation could not be expected and - as one can see now - one dependence (from oil) would only have been traded with another (from the not at all inexhaustible uranium). The nuclear vessel's operation is certainly enviably free of emissions, but the entire chain of manufacture of nuclear fuel and consequent waste disposal is a gigantic industrial operation - and not at all free of emissions. Moreover it has to face strong reservations in the age of global terrorism.

In the last two decades there have been astonishing developments ashore concerning sustainable energy production and utilization - one may recall the wind generators and the solar technology. They are certainly not yet fully competitive in economic terms with the established energy technologies based on fossil fuels and thus enjoy - controversial - government support. But they reduce increasingly the society's dependence from the imported fossil energy resources, the price trend of which has generated last year a feeling of threat and blackmail with governments, companies and last not least individuals.

Specifically in the 1980ies fresh attempts were made to reconsider well-proven propulsion technologies and to put them to practical use again also in the shipping sector. Namely the wind propulsion, without which the world would not have been „discovered“ and an early „globalisation“ in the 16th century would not have taken place, inspired not only enthusiasts to absolutely serious approaches (Dyna Rig, sailing surface rig, Indosail Rig, etc.). In spite of some promising attempts however (Priebe, P., 1986); (RINA (Hrsg.), 1975), the soon again collapsing oil price shattered all concepts, accompanied by some malicious comments from the shipping community, that no modern shipping could be operated with such „obsolete“ technologies, due to their assumed lack of reliability, speed and big cargo volume potential.

After this sobering scenario the question arises, if and how could shipping be prompted to consider not only a more economic operation but also a contribution to the solution to the ever more urgent climate and environmental problems – a topic presently very much discussed. One may wonder why this issue arises so belatedly considering the fact, that in no other

transportation sector it is so simple to turn free environmental energy to practical use. In contrast to railway, cars and aeroplanes a vessel can quite simply - set sail!

Chapter 3: The dimensions

In order to get an idea about the dimensions and the possible reduction potential for consumption of energy and emissions, it appears reasonable to provide an overview about the worldwide shipping activities. After all a project, which under an emissions' point of view should be as widespread as possible, must compete successfully in the shipping markets, since only then it would be accepted worldwide over short or long - as in the past.

At the beginning of 2007 the merchant fleet of the world numbered about. 43,000 vessels (above 300 gt size) with a tonnage of about 1.01 billion dwt. The most sizeable vessel types are the tankers (about 8,200 units with 374 million dwt). The bulk carriers come next with about. 6,800 units and 357 million dwt). Container ships number about 3,900 units with 128 million dwt). And finally comes the general cargo vessel with roughly 17,200 units and 100 million dwt) (Heideloff, C.; Zachcial, M., (Edit.), 2007).

Resulting from these figures, the average value for the vessel's size is: for tankers 45.600 dwt, for bulk carriers 52.500 dwt, for container ships 32.800 dwt and for general cargo vessels 5.800 dwt. It must be noted, that container ships stand out by their more than average speed (20- 25 knots) - and thus also by their more than average fuel consumption - while the remaining vessel types sail with an average of 10 - 15 knots.

Modern tanker and bulk carriers in the considered average size of 40 - 50.000 dwt have an average, daily fuel requirement of about 35 mton heavy fuel oil - equivalent container ships consume up to the double or even triple more. At assumed 320 operational sea days a year (the rest shared between port days and yard days) such an average tanker/bulk carrier has a fuel consumption of about 11,200 mton heavy fuel oil per year. Applying this finding roughly on the vessel type numbers, we arrive for tankers at about 92 million mtons and for bulk carriers at about 76 million mtons of fuel per year. Container ships with - due to their speed - substantially higher fuel consumptions - and general cargo vessel with - due to their small sizes - less consumptions are not considered. In any case it becomes clear, that worldwide shipping has an annual consumption in an order of a three-digit million tons of heavy fuel oil. This reflects a dimension, where the idea of savings may be appropriate - especially on the background of the cargo volume transported by these operations!

In this context another aspect has to be considered. The heavy fuel oil used in shipping is actually a residual product of the refinery industry and – when onshore – has to be treated as a special waste. Its effects on, over and in the oceans have been neglected till recently, but there are indications, that they are more detrimental as assumed up to now. That emphasizes the importance to ponder about the avoidance or at least reduction of its use, which automatically implies the questioning of the actual vessel propulsion technology. It is understandable that the implied industries - shipowners, shipyards, oil companies, etc. – would not be very happy with this. However, they also carry responsibility for the environment!

If one considers furthermore, that the actual price for 1 mton bunker (heavy fuel-) oil is in excess of the US\$ 500 mark (Woodward, D. (Edit.), 2008) and shows an increasing tendency, then one arrives at bunker costs for worldwide shipping in the order of a three-digit billion US\$ amount. Ships do not only consume heavy fuel oil during the voyage; also in port they

run generators and increasingly port states prescribe the use of twice as expensive MDO (marine Diesel oil) in order to reduce the impact on the local environmental.

In this context it may also be useful to ponder about the macro-economic effects of a less expensive shipping activity. Anticipating on conclusions stated below one can assume that advantages derived from a reduced shipping expenditure may have a beneficial effect for those countries which export mainly raw materials in bulk. Their terms would tend to become more favourable and thus more competitive, which should improve their export.

Chapter 4: Parameters of Shipping

Since the last great initiative towards a less energy intensive shipping in the 1980ies, some of the fundamental parameters of shipping have changed dramatically. While the demand for transport services of all kinds has constantly increased since, the shipping industry permanently sought to differentiate its offer, having been accustomed to a worldwide competition since early times. Moreover the introduction of the container revolutionized the trade in a hitherto unknown way and intensified the integration of some types of vessels into a fully rationalized, logistic transport chain.

According to this differentiation there is no magic recipe for the application of newer, energy saving propulsion technologies which also reduce emissions. So, even the idea to install rig and sails on a modern, giant container vessel appears absurd and further, when considering the worldwide, relatively stable wind systems, even to a layman some courses may appear against any logic. Accordingly, it is important to adapt the different propulsion technologies to the parameters as best as possible in order to avoid less than optimal results, which would not at all benefit the introduction of these technologies.

The main parameters which have changed in the last decades are the following:

Types of vessel:

Based on the universally applicable sailing vessel of earlier days ships have branched out into a great number of specific vessel types in order to address all transport requirements as best as possible. One can almost speak of a biological process of best choice in Darwin's sense of the „survival of the fittest“.

To demonstrate this principle, one may just enumerate some of the main types of vessels: tanker, bulk carriers, general cargo vessels, container ships, cruise vessels, ferry-boats and many more. As already mentioned it is immediately clear, that for instance container ships with their “container mountains“ as well as their apparently indispensable high speed cannot be meaningfully equipped with rigs and sails. However, tanker and bulk carriers with their extended „empty“ decks would be well suited for such a conversion, especially when some other parameters are also fulfilled.

Sailing cruise vessels exist already and enjoy great popularity; however they are limited to an exclusive niche market, especially since they often cater for the „nostalgic“ feeling of their clientele - and not necessarily for the most recent technology.

Vessel sizes:

In the eternal chase for the best possible economic performance and under the iron law of the „economies of scale“, vessel sizes of all types have registered a tremendous increase in the last decades and surpass by large anything which carried sail in former times. Had the famous „Preussen“ with her roughly 8,000 mton been a „super vessel“ a century ago, she would today just qualify for the class of the smallest bulk carriers.

In this context the not unimportant question arises, how such gigantic dimensions could still be moved and controlled with wind power. It must be considered however, that the applicable technology has also made immense progress. One may just recall the modern, computer assisted winch technology, the completely different materials for hull, sail and ropes, the modern construction principles, the meteorological navigation, etc.

Cargo flows:

During history cargo flows have always been changing. Who still remembers today the old „race course“ of the large sailing vessels before World War I, which carried guano from Peru via Cape Horn to Europe (Prager, H.G., 1979)? And who would have foreseen 20 years ago the cargo volumes, which emanate from/are carried to China and India today?

However, on one parameter modern windships are as dependent as the old ones: on the wind! As it doesn't blow everywhere constantly, the art of sail navigation consists as before therein to carry adequate cargoes embedded in the regular, global wind systems. Because the parameter „wind systems“ has practically not changed in contrast to many others.

Energy prices:

The biggest change however has affected the parameter „energy costs“. After a century of practically stable and cheap oil prices, a new oil price development has set in beginning with the first oil embargo in 1973. Since then the oil price has increased more than tenfold and, considering gloomy scenarios like „peak oil“ and the continually growing demand specifically of the new threshold countries (Brazil, China, India, Russia, etc.), one cannot seriously reckon with a price decrease to the former, „paradisiacal“ price level.

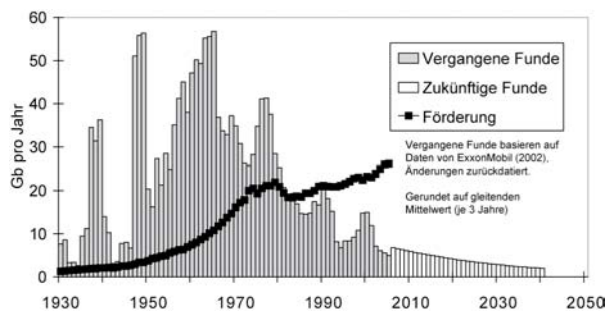


Fig. 1: Peak oil scenario

Ex ASPO Association for Peak oil Studies, 2006

Moreover the vessels' speed plays an important role, since the fuel consumption increases at higher speed more than proportionally. This is especially important for fast container ships. Due to their high speed they're not well suited for the use the wind energy and must hope for other developments (fuel cell?).

In other words: high and further increasing energy prices (for oil, coal, gas and even for so called biological fuels) will stay with us in future and will lead increasingly to economic and ethical problems. Shipping will also suffer from them. Anyone who doesn't prepare himself for this scenario acts in an irresponsible economic way!

Environmental impositions:

At the same time he increasingly acts also in an ethically irresponsible way. The great context between: consumption of energy - emissions - ecologic damages and necessary „repairs“ of the same in the future is no longer seriously contested today. Moreover there are increasing fears, that the so often conjured „logic of the market“ (high demand - low offer = higher prices = lower consumption) will come too late to positively influence the long-term negative effects of the climate change.

As a consequence of this change of political mood impositions have already been decreed in order to discriminate the energy consuming activities respectively to make them more expensive. A worldwide, political process has started, from which not even the in this respect rather reluctant world powers can subtract themselves and which increasingly generates such impositions.

In the meantime the emission certificates trade has been established in Europe after a rather difficult start in 2005. In the context of this paper however it is of no importance, since up to now it does cover neither the aviation nor the shipping industries. Nevertheless there are increasing efforts to terminate these privileges in the same extent as it is recognized, how both activities contribute to the emissions. Their characteristics as worldwide activities naturally imply also a worldwide contribution to the emissions. In an argument from the contrary it stands to reason, that a reduction of emissions in these activities would also have a worldwide, positive effect!

Chapter 5: The Solutions

The most recent marine engine technology based on fossil fuels has probably reached an optimum and may lead into a dead-end in the long-term. In spite of all - increasingly expensive - technological perfection it will not be able to face the two challenges: on one side the growing scarcity of these fuels will trigger a price trend which will increase transport costs and thus cause economic shifts. On the other side the above described effects of their combustion will enforce subsequent environmental „repairs“ and preventive political impositions. Both developments will have massive effects on shipping, transport flows, macro-economic developments, environmental conditions and climate. The control respectively attenuation of these problems will increasingly require financial and technological resources.

All these aspects imply a fundamental questioning of these propulsion technologies. Fortunately and as already hinted, the search for alternatives is much easier as in other economic sectors, since the energy resource „wind“ is available over the oceans free of charge from the very beginning.

With wind-driven vessels the world has been discovered and sailing vessels were the vehicle of an early globalisation from the 15th century onwards. Their further development had been discontinued due to mainly economic reasons 100 years ago. In so far it is understandable that their re-introduction can also only succeed, if they are economically successful in comparison with/to comparable motor vessels.

From the previous chapter about shipping parameters results that windships are not equally well qualified for all tasks in shipping. For instance, they would not be indicated for short

trips to changing destinations (the embedding into the wind systems would hardly be possible), expensive cargoes (low speed; problem of interest on the cargo carried), cargoes above the main deck (for instance container), routes through windless regions, etc.

In the argument from the contrary results that windships are best qualified for transport of cheap bulk commodities in large volumes on long voyages, embedded into the worldwide climate and wind systems and also, that they must have an auxiliary propulsion in order to enable them to traverse not so windy regions and coastal waters without much delay. Thus the idea takes shape of a wind-driven bulk vessel of medium size, which carries mainly agro products (grain, fertilizer) on intercontinental routes. Under certain circumstances middle-sized tankers/product tankers would also be conceivable, as long as their routes would be compatible to the wind resources.

The old log books of legendary large sailing vessel as the „Potosi“ and the „Preussen“ document astonishing performances concerning speed, days-work and total voyage times, which were all achieved without a drop of fuel, since the vessels at that time had still no auxiliary propulsion (Schwab, H.-B., 2003). It shows the savings potential the wind power offers, as long as the above mentioned combination of parameters is obeyed.



Fig 2: Example for an INDOSAIL rig
Ex Cruise vessel project INDIGA,
2005 Geesthacht

During the past century many intelligent minds have worked on the problem of a more efficient use of wind power in shipping. In the meantime a large number of promising approaches has developed, which however have all

their advantages and drawbacks and which have all failed due to the low bunker costs at the time (Schaale, H., 2003). However, in order for them to influence the reduction of fuels and emissions, they must find profitable application in as many as possible large sectors of shipping like in the bulk cargo trade (liquid and solid). Individual respectively niche applications (for instance cruise sailing vessels, Flettner rotor vessels) may certainly take over trailblazer functions, even if they are hardly of any relevance within this issue.

In this context and since a few years there exists an interesting special development of a sail kite by a young Hamburg-based company SKYSAILS. By this system container ships can also profit from wind power, as otherwise they cannot be equipped with more or less traditional riggings due to their „container mountains“. In spring 2008 this kite system had undergone its first trial under real conditions (Skysails Homepage (2006).



Fig.3: Example of a kite rigging

Ex SKYSAILS Homepage
<http://www.skysails.de>

With regard to the above envisaged vessel (bulk vessel for intercontinental routes) the well tried square rigging does also appear in a new light, since it enables the optimal use of the global winds on the intended courses with a relatively reduced technological input. Fuel savings up to 75% in comparison to an equivalent, conventional bulk vessel appear possible (Warnecke, H.-J., 2005). On these assumptions is based the project SAILLOG of Capt. Schwab, which has the potential to compete most successfully in wide sectors of the medium class of bulk vessels („Handymax“) (Schwab, H.-B., 2006, 2007); (www.saillog.de <<http://www.saillog.de>>).



Fig.4: Example of a modern square rigging (system Schwab)

Ex project SAILLOG, 2008

The total operating costs of such a vessel is reduced by about 25 %, considering that the crewing requirements are not higher as for an equivalent, conventional bulk vessel. An automatic and electrical handling system enables the vessel to be run by such a reduced crew, a system which has been patented already.

Actually marginally better results may be obtained with substantially more expenditure, but the costs for the then necessary „high-tec“-technologies can hardly be borne by cheap bulk commodities. An example for this is the super yacht „Maltese Falcon“ of the US billionaire Tom Perkins, which was equipped with the „Dyna-Rigg“ invented by the Hamburg engineer W.Prölss in the 1960ies (Wikipedia, (2008). It was the first time that this system was installed in a real-size vessel and apparently it has performed well up to now (“Maltese Falcon” Homepage)



Fig.5: Example of a Dyna-Rig (System Prölss)

SY „Maltese Falcon“, Ex Maltese Falcon Homepage, 2007

Chapter 6: What has all this to do with the climate?

From all the explanations above one can draw the following conclusions:

1. Considering gloomy „peak oil“ and climate change scenarios, shipping will also have to face new challenges and massive impositions. Due to its worldwide activities, it may subtract itself from such interventions temporarily, but it will not be able to prevent them in the long run.
2. It is good to recall that the use of sustainable energies in shipping - in particular of the wind power - is more easily feasible than in other sectors, as no new, untried technologies are necessary and it can be applied instantly. On this basis, really new technologies (for instance: fuel cell) can be developed to technical maturity.
3. Considering the worldwide activities of shipping, fuel savings would also have worldwide, positive effects on emissions.
4. This requires an as much as possible extended application of wind energy technologies in shipping, which however would only be guaranteed in the „large bulk trades“ (tankers, bulk carriers).
5. Considering the above computed, annual fuel consumption of various hundred million mton heavy fuel oil in the two largest classes of vessel types alone, one can imagine, what could be achieved for the emissions and thus for the climate by a 75% reduction of fuel.
6. The need for transport services of all kinds and thus also for vessels tend to increase further. Considering that vessels are anyhow and by far the most environmental friendly means of transport and that they will remain so, it would almost be an environmental crime not using the perspectives of wind-driven large vessels, the potential of which can be developed without much additional effort.
7. There is no immediate, magic solution for climate protection and reduction of emissions. In their clear technological and economic delimitation and their worldwide operational possibilities, vessel units are the ideal vehicle for a concrete application.
8. With the foreseeable inclusion into the emission certificates trade shipping, when using modern windships, will be able to tap a new source of revenue, which will not be accessible to conventional, engine-driven vessels.

9. Due to the smaller fuel volumes carried, the risk of pollution by oil in case of an average is accordingly smaller - and should reflect in more favourable insurance premiums.

The quintessence of these conclusions is, that there exist already today quite concrete solutions for the reduction of fossil fuels and thus also of emissions. It appears imperative to apply them and not to reject them as “obsolete“. After all, not everything termed as „old“, is outdated and not everything „new“, is better. It always depends of parameters, which keep changing all the time!

Thus, in the same way as the apparently iron „Time is money!“ has resulted in an economic development which has increasingly damaged the environment, its inversion „Money is time!“ can generate conditions more acceptable to mankind and environment alike. Modern windships are best suited for that end and would be available immediately – if there is the will for action!

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