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Innovative green ship design

Competitiveness from an energy efficient and environmentally friendly point of view – green shipping – is an important focus area for the Danish Maritime Authority. This is pursued within two strands, namely regulation through the IMO, on the one hand, and research, development and innovation, on the other.

The second strand is enacted within a Danish, a European Union and an international perspective and is organized in dialogue with the central stakeholders. An important forum is the Partnership for Climate Responsibility within the Danish Maritime Cluster – the Blue Denmark with participation of ministries, universities, knowledge institutions, industry organizations and private companies. Furthermore, the work embraces environmental issues.

One of the outcomes of the discussions in this forum is the project ”Innovative Ship Design” with:

”Development of partnerships between companies in the Danish Maritime Cluster and shipyards on continuous innovations of new built ships supporting green shipping[1].”

The aim is hereby to develop the competitive edge of green shipping and create advantages for the central stakeholders in this development. Here, it is imperative to underline that both Danish and foreign central stakeholders will benefit and that the co-operations are primarily between industrial partners.

The aim of this project is to facilitate the formation of partnerships aiming to develop green shipping.

[1] The original formulation was ”Development of partnerships between companies in the Danish Maritime Cluster and shipyards on development of innovative ships supporting green shipping.” The title has been slightly adjusted to match the business model for shipbuilding within the context of this project as explained in the report.

Shipyards in the Far East are the most important suppliers of ships to the Danish merchant fleet and, consequently, the project focuses on co-operation between Far East shipyards and Danish shipowners and marine equipment manufacturers.

The project idea has been developed in close co-operation between Danish shipping companies, equipment manufacturers, maritime consultants and industry organizations. Subsequently, the results of the discussions with the Danish stakeholders were tested at meetings with shipyards, organizations and government officials in the Far East.

The Danish Maritime Authority has been tasked to facilitate the discussion and focus the outcome.

This report summarizes the work and presents recommendations.

The business model for shipbuilding within the project context

To start with, it is worth emphasizing that the project concentrates on ships built in series and not on one-off ships. Furthermore the work has a strong bearing on new buildings based on existing ship designs rather than on new designs[2].

The corresponding shipbuilding business model is characterized by an ongoing development of products and processes, especially when building in series. From a ship innovation point of view, this model can be described as incremental in contrast to breakthrough innovation, which has the potential of altering the business model for shipping.

The background for the innovation model is found in a thinking based on the following:

- It is possible to allocate the developmental and design costs and, partially, the production planning costs to the first ship.
- Significant cost advantages are derived from building in series; however, it is difficult to put a lower limit on series.
- Economy of scale in building and procurement.
- Incremental innovation within the different ship types.
- Innovations in the design of engines, pump systems and hull shapes will be extended to new ships, hereby creating a short window of opportunity to exploit these as first mover advantages.
- Ships within their own class of particulars compete in the same international markets.
- Charterers think in standard ship types with regard to cargo, draft and speed, etc.

[2] Sometime a shipowner comes with an outline design to shipyards for a ship which do not seems to fit existing designs. But often the shipyards use development of existing ship designs as the starting point for negotiations with the shipowner.

But nevertheless it is important to obtain first mover advantages, including being at the forefront of new regulations and demands from cargo owners. The following sources for reaping these advantages can be listed:

- The building process.
- Flexibility in relation to standard designs for changes and innovations.
- The development of flexibility in the shipbuilding process when trying to accommodate individual shipowners' demands.
- Sourcing of equipment.

Best practice examples can be valuable in creating models for extended flexibility able to harvest first mover advantages.

The need for obtaining first mover advantages is demonstrated by the fact that the shipyards face a paradigm shift because of the financial/economic crisis and an overcapacity in the shipbuilding sector implying a move from a seller's to a buyer's market. Furthermore, the environmental and climate change agenda demands more environmentally friendly and energy efficient ships.

As clear evidence of this thinking, the following drivers can be mentioned:

- The Energy Efficiency Design Index (EEDI).
- The Ship Energy Efficiency Management Plan (SEEMP).
- The Energy Efficiency Operational Indicator (EEOI).
- The market-based instruments on CO_2
- The IMO regulations on the reduction of NO_X and SO_X emissions.
- Ballast water treatment in relation to IMO regulations and local regulations.
- Large international companies focus on their carbon footprint and environmental impact from a supply chain perspective.

Especially the EEDI and the emission and ballast water regulations have a great impact on the design and construction of new ships and can be regarded as major drivers, while most of the other drivers have a more soft character addressing the management of ships. But if cargo owners demand ships operated according to the management plan and the operational indicator and put up benchmark values, these indexes become "hard" design parameters.

Despite the above business model, some ship designers have been successful in creating ship designs capable of serving different market segments and hereby creating alternatives to existing shipyard designs[3].

There is an inconsistency with regard to the use of fuel and shipowners. Some shipowners pay their consumption of fuel as part of their running

[3] For example Grontmij|Carl Bro with the Diamond and later the SeaHorse design.

costs, while others are paid by the cargo owner. Furthermore, tonnage providers do not pay for their fuel consumption. Hereby, shipowners have different incentives with regard to their focus on ships' energy efficiency.

The business model for shipbuilding involves many stakeholders and the interaction between these stakeholders is crucial for a successful shift of paradigm to green shipping; therefore, this report focuses on co-operation and networks as well as partnerships to create the necessary innovation.

However, it must not be forgotten that orders for new ships are often placed under great time pressure, and it is important that the legal contracts create room for innovations.

The networks, co-operations and partnerships can be seen from the point of view of a specific ship (series) as well as in broader terms as a running dialogue between shipyards, equipment manufacturers, consultancy firms and development and innovation projects. The Danish project Green Ship of the Future can be seen as such a project.

Central actors and motives

In the following, focus will be on the motives and characteristics of the central actors in the shipbuilding process and the framework they operate in.

Shipowners

From a shipowner's point of view, the "right" mix of Capital Expenses (CAPEX) and Operating Costs (OPEX) is crucial. Here, it is important to stress that the energy consumption is different for the different ship types with fast going container ships as the most energy demanding type and slow going bulkers and tankers as the least energy demanding type. This means a different trade-off between CAPEX and OPEX

In an ideal world, the mix is decided by the maximum rate of return on the shipowner's equity. High CAPEX must, other things being equal, express higher quality in relation to energy efficiency, operating costs, maintenance, safety, and environmental impact, etc.

These quality factors are different from an economic approach. Energy efficiency means saved costs and can be looked at from:

- An energy production point of view – how efficient is the process?
- A propulsion point of view, including auxiliary systems such as pumps, heating and air conditioning systems, etc. – how energy efficient are the different consumers?
- An operational point of view with weather, routeing and trim systems, etc.

For all these viewpoints, it is possible to set up business cases showing the maximum rate of return[4].

But this business case is dependent on three issues: The technical functioning, a general uncertainty about new or improved technologies and economic factors such as the price of fuel.

An alternative evaluation instrument is the anticipated payback period. The shorter the payback period, the greater the incentive to make the investment! Further, it is possible to calculate the payback period using alternative assumptions with regard to fuel costs, the effect on energy efficiency, etc. and hereby arrive at a sensitivity analysis.

At present, it is not possible to make the corresponding calculations with regard to environmental impact, safety and work environment. Here, it is the basic values of the shipowner or, as it is expressed these days, his Corporate Social Responsibility (CSR) which will be decisive.

A third driving force embracing these two dimensions is preferences expressed by the transport buyers and end consumers. They can make demands with regard to the ship and its operation as such to qualify for the transport and then choose the most competitive of the short-listed ships. This short-listing will be according to the CSR policy of the transport buyer.

As a fourth dimension, coming regulations, known as well as anticipated, have a bearing on the investment decision.

Most shipowners are dependent on financing from the capital market and the capital providers have their own views on the business case trying to balance their portfolios.

Finally, shipowners are not a standardized commodity, but rather span from owners taking care of commercial and technical operations as well as manning to mere tonnage providers bare-boat chartering their ships to other shipowners or operators. Furthermore, in case of some shipowners the charterer pays for their fuel consumption.

The above demonstrates the complex environment in which shipowners have to decide on the right mix between CAPEX and OPEX. Furthermore, the different types of shipowners have different incentives to

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[4] Under the discussions, the economic term TCO – Total Cost of Ownership has been mentioned several times. A TCO analysis includes the total cost of the investment and operating costs. It is used by investing companies, credit markets and financing agencies and can be seen as a tool to compare costs of different investments. These comparisons embrace the problems with regard to CAPEX and OPEX. The TCO considerations result in the alternative cost profiles and evaluations necessary for calculating return on investment, internal rate of investment, economic value added, etc.

choose their right or "imposed" mix. Here, the bottom line is that CAPEX are fairly accurate, while OPEX are more dependent on unknown factors.

Shipowners have different abilities to express their own needs and to engage in a technical dialogue with the shipyards and the equipment manufacturers. Here, ship design companies can enter the discussions on behalf of/supplement the shipowner in the design discussions and further on in the construction phase.
Discussions undertaken in connection with this project on innovative green ship design with regard to shipowners show the following:

- There seems to be an asymmetry between shipowners and other maritime industries as the shipowners reveal more openness to a dynamic balance between CAPEX and OPEX than perceived by the shipyards and equipment manufacturers who claim that shipowners' main focus is on low CAPEX.

- There are differences between shipowners according to their business model, with liner shipping companies paying for their own fuel as part of their operating costs as the most CAPEX/OPEX trade-off willing and the mere tonnage providers as the most trade-off unwilling.

- Shipowners are moving away from a "technical backbone" towards a more economically oriented perception with less emphasis on technology. This creates a new form of dialogue between the shipowner and the yard characterized by "shopping around" instead of long-lasting relationships based on the technological development of the ship.

- International regulations are of crucial importance and can be perceived as either "setting the bottom-line" or as an innovation driver.

- Predicted savings of energy and maintenance costs are difficult to document because the measuring of these parameters is not standardized.

<u>Shipyards</u>
The financial/economic crisis has created an overcapacity within the shipbuilding sector. Furthermore, shipbuilding is regarded as a strategic industry for countries such as South Korea and China. This is also seen in the financial, research and development backup for these industries.

The change of the shipbuilding agenda from a seller's market to a buyer's market has created a strong perception of the need to develop the shipbuilding process as well as the quality of the product itself in order to be competitive. The way ahead for the shipyards can be seen as the development of new designs for the market or a more passive approach where the shipowner is the decisive force ordering a new ship.

The different shipowners as described above create different possibilities for the shipyards.

From a general point of view, there are distinct differences between South Korean and Chinese shipyards. The large South Korean shipyards seem, to a wide extent, to have in-house competences with regard to research, development and innovation, both from a shipbuilding and a ship innovation point of view. Chinese shipyards are more focused on shipbuilding and the production process, rely on a backup system with regard to research, development and innovation and are strongly backed by the Chinese government. Both structures create room for competitive shipbuilding if the shipowner engages heavily in the ship design and building process, often with a strong back-up from ship designers and classification societies.

In general, this emphasizes a critical factor in the relation between the shipyard and the shipowner: Who is responsible for the different features of a ship when the demands for the shipyard are expressed as functional ones rather than as construction specifications. If the shipyard is uncomfortable with the setup, it will demand a higher price to compensate for uncertainties in the development costs and the risk of not meeting the demands.

This can be seen as part of the wider trend in IMO regulations with a shift from prescriptive regulations demanding a specific solution to functional or goal-based regulations leaving room for different solutions and demanding a higher ability for innovation on the part of the shipyard. The energy efficiency design index (EEDI) under negotiation in the IMO has unanimously been mentioned as a driving force if adopted for shipbuilding and encompassing a wide range of technical innovations. It will have an impact as both a mandatory and a voluntary index.

Both relations have a tremendous bearing for a successful transition of the shipbuilding industry and demand expansion of the research, development and innovation base and, hereby, skills and can be met by both the “South Korean” and the “Chinese” model.

A supplementary way ahead in order for shipyards to obtain competitiveness is by means of outsourcing. To succeed here, shipyards become more dependent on supply chain considerations outside the shipyard, seen from both a logistical point of view and a value chain point of view, capturing new competitive technologies. But as seen above, this is not an easy task because of the wide differences between shipowners and their perception of the right mix between CAPEX and OPEX.

Discussions undertaken under this project on innovative green ship design with regard to shipyards show the following:

- The shipbuilding market has shifted from a seller's to a buyer's market and no one expects this situation to change in the near future.

- Regulations have a strong impact on shipbuilding.

- There seems to be different perceptions with regard to whether prescriptive regulation hampers innovations compared to goal-based standards.

- Regulation based on functional demands/goal-based standards places new knowledge-based demands on shipyards.

- As regulations, economies of scale has a strong impact from the shipowners' (operation) as well as the shipyards' (building in series) point of view.

- The shipyards call for new development projects with shipowners to obtain mutual competitive advantages.

- Equipment suppliers must be more visible in their day-to-day co-operation with the shipyards and create value through new technological solutions and, at the same time, embrace the need of the different shipowners by offering different solutions with regard to quality and price.

- Shipyards go for systems, and not components, which have a bearing according to the equipment manufacturers.

- Sea trials stipulating draft, speed and power needs are carried out under still water conditions and, thus, do not embrace the operational profile of the ship after delivery.

- Shipyards are very reluctant with regard to expanding warranties.

- Predicted savings of energy and maintenance costs are difficult to document because of measuring problems. Furthermore, no international standard is available at present.

Equipment suppliers

Equipment suppliers become increasingly important as shipyards apply a business model based on the outsourcing of work to reap economies of scale. This also implies more concentrated research, development and innovation efforts as the equipment manufacturers' customer base spans over many shipyards.

From the shipyards' point of view, the demand is oriented towards systems rather than components. From an energy saving point of view, a component can bring about very high savings compared to an alternative

component. But if its energy consumption is very limited/hardly measurable compared to the total energy production on board the ship, its potential will not be of value to the shipowner.

This also demonstrates the need to think in systems encompassing small energy savings as well as larger to bigger measurable savings.

It is crucial for the equipment manufacturer to demonstrate the quality and reliability of his equipment, and there seems to be a long way from the test bed to proven reliability on board a ship.

For complex technologies involving deliveries from different manufacturers, the shipyard will demand a single supplier to take responsibility. This counts at least for the initial phase, but when the technology becomes more mature and the operational experience is good the shipyard will consider taking over the responsibility to earn the system integrator premium.

The majority of regulations on emissions, safety and working conditions can be met only by innovations made by the equipment manufacturers, and in general they are very innovative.

Discussions undertaken under this project on innovative green ship design with regard to equipment suppliers show the following:

- A strong trend in the demands from shipowners and shipyards towards systems rather than components.

- A world-wide ship servicing system is necessary in case of operational problems. The same applies to maintenance.

- The equipment suppliers must be able to deliver over a broad range of quality/functions for a given component/system as shipowners have different demands.

- Equipment suppliers are strongly innovative.

- Innovations from equipment manufacturers are imperative for the development of new and the improvement of existing ships.

- Equipment manufacturers seem to claim that a shipowner will get a better ship if the equipment manufacturer gets a more central role in the discussions leading up to the ordering of new ships.

- Shipyards want stronger day-to-day co-operation with the equipment suppliers/demand more visibility.

- There is a long way from the test bed to installations on board a ship, and shipowners and shipyards must be more willing to take a risk in order to harvest the benefits from new innovations.

- Predicted savings in energy and maintenance costs presuppose a specified operational profile.

- Violations of property rights are seen as a major threat to equipment manufacturers.

Others
Here, ship designers, consultancy companies, educational institutions and research and development institutions can be mentioned.

Furthermore, the charterers taking care of the chartering of ships must not be forgotten as the value of a ship basically depends on their earnings.

Recommendations
On the basis of the above, the negative conclusions with regard to the building of innovative green ships are the following:

- Shipbuilding is a crossroads of conflicting interests.
- Measurements of fuel savings are strongly subjective and based on belief. The same counts for other green features such as emissions, etc.
- Nobody wants to take a risk.

The implication of this conclusion is that regulation becomes the main driver. This means that the potential for innovative ships will not be exploited in full as innovation will not be set free.

But a more positive conclusion seems more likely as there are many dynamic factors in the market paving the way for green ships. This being said, regulations no doubt have a major impact on quality, including the environmental and energy performance of new ships, and hereby on the innovation process.

A clear implication of this is that regulations must be designed to create new innovations through a clear focus on the aim rather than the method.

From a shipowner's perspective, not all shipowners have the potential – or need – to order new innovative ships and their orders will typically be placed for a shipyard's standard ship types. When this is said, it must be remembered that some tonnage providers build ships for rather long charters and that the charterer often puts up conditions for these ships with regard to design and equipment.

Large shipyards are able to engage in such discussions either on their own or with the backing of a system consisting of ship designers, innovation centres, etc. Equipment manufacturers are of great importance in this process, but they seem to be in a more "unclear" situation as the contracting partners are the shipowner and the shipyard, where the latter is responsible for the sea trial and guarantee period after delivery of the ship.

This system is supplemented by guarantees from the central equipment manufacturers with the shipowner as the beneficiary.

Another business model is possible if a skilled shipowner more or less takes control of the shipbuilding and design process. This often happens with rather small and newly established shipyards.

If an equipment manufacturer engages in expensive development work with a shipyard, this means transfer of knowledge to the shipyard and expenses. This is done only with the expectation of later return/new orders.

For all of the below-mentioned "possible ways" for new innovative green ships, it is important to stress that the necessary legal provisions must be stipulated in the contract between the shipowner and the shipyard.

Model tank assistance for the operational profile of the ship

Shipowners often see advantages in modifying the hull shape and propellers, etc. for the specific trade for which the ship is ordered. The basis for these considerations is based on the shipowners' experience with regard to engine load, draught, weather, current, etc., and this creates uncertainties for the shipyards as these considerations cannot fully be reflected/documented in the normal sea trial procedures.

The sea trial is carried out in still water and at a specified draft, speed and expected power consumption, which is often different from the normal operating condition.

The initial EEDI work basically relies on model test verification with the important exception that an independant verifier must issue a report of pre-verification of EEDI.

This report can be seen as a starting point for further calculations and investigations with regard to improvement of EEDI and to more specific trades as mentioned above. This includes further towing tank tests often involving external and independent expertise/experience covering the operational profile and not only the pre-verification condition (sea trial condition).

Hereby, shipowners supported by individual towing tank tests take the main design risks. But it is worth mentioning that such assistance demands an in-depth knowledge with regard to the operational profile and is most value creating for ships with high fuel consumption.

A dynamic "maker's list"

The shipyard wants to test the market for the components and systems to be delivered by the equipment manufacturers through a "maker's list". The starting point for this list are functional demands and a "negotiated agreement" between the shipowner and the shipyard with regard to possi-

ble suppliers; often 3 possible suppliers for each item. It is up to the shipyard to tender among the possible suppliers and the shipyard has a strong inclination to choose the suppliers with the lowest price.

The key question is whether it is possible to formulate the maker's list in a more dynamic way by opening up for alternative solutions implying higher energy efficiency, lower maintenance costs, etc. Discussions with shipyards have shown openness to this possibility on the following conditions:

- Compensation for additional costs.
- The schedule for building the ship must be respected from a production design and planning point of view.
- It must be clear what has to be modified and/or altered.
- The implications for the sea trial and the guarantee period must be the responsibility of the shipowner – if relevant.

These are the initial considerations of the shipyards, and naturally the competition pressure can have a modifying impact on the willingness of a shipyard to change its position. But basically it reflects the fact that a greater risk must be compensated financially.

The last dot may reflect that it is difficult to measure the consequence of a fuel saving device during the sea trial as well as later when the ship is in operation and embraces the discussion on the relation between CAPEX and OPEX.

All this boils down to the shipowner's assessment of the ship and the future market conditions from an expense and an income point of view as well as in consideration of his business model and financial capabilities.

The shipyard, on the other hand, will make its evaluations on the basis of an assessment of the competition, the possibility of selling a similar design to other shipowners, etc.

<u>Open book co-operation</u>

Basically, the shipowner and the shipyard are contractual partners with regard to the ship and the aim of the shipbuilding contract is to create clarity and transparency with regard to the ship.

But for innovation projects encompassing a specific feature of the ship it can be difficult to draft an ordinary contract stipulating the responsibility of the shipyard. For such a feature an open book thinking can be applied.

According to this thinking, it has to be decided what costs must be accountable and with what margin indirect costs must be covered. Furthermore, it is important to create transparency in the accounting system.

The partners subject to the open book system can be the shipyard and/or the equipment supplier. From the shipowner's point of view, its trust in the capabilities of the shipyard and/or the equipment supplier has a great bearing. Long-lasting relationships will, other things being equal, create a good basis for the establishment of an open book co-operation.

ESCO models

According to the Energy Saving Co-Operation model, a supplier of a new energy saving technology is at first paid by the energy savings during operation and, after a specified period, the energy savings will benefit the owner. Furthermore, the ESCO model guarantees that savings are obtained. If not, compensation must be paid to the contractual partner and, if the savings are greater than promised, the added saving will be divided between the two partners.

The model has different possibilities with regard to financing. The financing can be provided by the ESCO company or by its partners or the financing can be arranged by the owner himself. In the latter situation, the owner will get the savings from the beginning and, at the same time, get a guarantee for the savings.

It is the ESCO company which provides the owner with new expertise and operational awareness.

As mentioned under the "Equipment supplier" heading above, investment in energy savings must as a starting point have an economic value for the shipowner. This means that the energy savings must have an impact on the energy consumption. Many minor savings add up to measurable savings! At the same time minor savings can be seen as part of the shipowners' CSR profile and awareness of energy consumption.

The model can be used for new-buildings as well as for retrofits, but its main stumbling block is the assessment of the actual energy saving. On the other hand shipowners often come with statements like "we have saved x % fuel" by installing a new propeller type, modifying the bulb or installing a new heating, ventilation and air conditioning system, etc. Furthermore equivalent statements are heard from equipment manufacturers, ship design companies and shipyards.

This can be considered fertile ground for developing the ESCO thinking[5] but mutual trust between the partners is needed. This must be reflected in an ESCO contract.

For some systems and components, the measuring problem seems to be of minor importance as there is a well known relationship between the

[5] A conference in the fall 2009 on green technologies, including ESCO's in the Danish Society for Naval Architecture and Marine Engineering confirms these considerations.

work to be done and the energy consumption. Here, pump and heating systems can be mentioned.

Concluding remarks
As stated in the beginning of this report, the aim is:

"Development of partnerships between companies in the Danish Maritime Cluster and shipyards on continuous innovations of new built ships supporting green shipping."

The work carried out identifies four 4 different avenues for such partnerships:

- Model tank assistance for the operational profile of the ship
- A dynamic "maker's list"
- Open book co-operation
- ESCO models

To make the partnerships operational, the contractual relationships and the innovation concerned are pivotal.

In the introduction to the description of the partnerships[6] it is stated:

"For all of the below-mentioned "possible ways" for new innovative green ships, it is important to stress that the necessary legal provisions must be stipulated in the contract between the shipowner and the shipyard."

The area to which these legal provisions are to apply must be delimited. Mostly, it is possible to attribute new innovations to special features of the ship as the business case applied in this report is incremental[7].

The innovation challenge is very different as regards ordered and potentially ordered ships. This demands a right balance between the innovation concerned and the contractual provisions between the shipowner and the shipyard and, eventually, the involvement of equipment suppliers.

An open book co-operation for a new cargo heating system and an ESCO model for a new pump system can be mentioned as more straightforward examples. A new hull and propeller design according to the operational profile of the shipowner is not so straightforward.

This report shows that the incentive structure is very different for the central actors – shipowners, shipyards and equipment suppliers. Furthermore, there are big differences within these groups measured in dimensions

[6] Re. Recommendations – last paragraph.

[7] Re. The business model for shipbuilding within the project context – second and third paragraphs.

such as risk taking, competences, preferences between CAPEX and OPEX and markets.

The implication is that the partnerships needed on continuous innovations of new built ships supporting green shipping must be developed on a case-by-case basis. Furthermore, the contractual relationships and the innovation concerned are pivotal to making these operational.

The contractual issue can be made more concrete as BIMCO's Standard Newbuilding Contract – NEWBUILDCON – can provide the necessary legal provisions for partnerships as described above.