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Summary:

The study has considered the feasibility of undertaking the procedures associated with the disposal of four vessel categories with respect to technology and economy within Europe, the wider European Economic Area and in neighbouring countries (Eastern Europe and Russia). The four categories are:

- Offshore structures
- Merchant fleet
- Inland waterway vessels
- Naval vessels

Findings and conclusions are based on assessments including the review of decommissioning and disposal decision factors, type and volume forecast predictions, established procedures, market opportunities, legislative framework and compliance expectations.

The report presents disposal forecast results for each vessel category and provides guidance on the potentials and opportunities of undertaking such activity in Europe. Limitations and requirements associated with decommissioning, dismantling and recycling/ re-use in a European context are discussed and recommendations provided. These are supported by background data and details presented in Appendices.

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1 SUMMARY AND CONCLUSIONS

The study has considered the feasibility of undertaking the procedures associated with the disposal of four vessel categories with respect to technology and economy within Europe, the wider European Economic Area and in neighbouring countries (Eastern Europe and Russia). The four categories are:

Offshore structures	Merchant global fleet
Inland waterway vessels	Naval vessels

Findings and conclusions are based on assessments including the review of decommissioning and disposal decision factors, type and volume forecast predictions, established procedures, market opportunities, legislative framework and compliance expectations.

The report presents disposal forecast results for each vessel category and provides guidance on the potentials and opportunities of undertaking such activity in Europe. Limitations and requirements associated with decommissioning, dismantling and recycling/ re-use in a European context are discussed and recommendations provided. These are supported by background data and details presented in Appendices.

Technical constraints and opportunities;

From initial findings and volume forecast predictions, it has been shown that:

- Disposal policies differ widely between the categories
- The majority of vessel scrapping activity relates to merchant vessels (conventional ship scrapping)
- Currently this is undertaken almost exclusively outside of Europe
- The main scrapping activities take place in India, Bangladesh, Pakistan and increasingly in China
- Many aspects of current principles and methods adopted and in use are non-compliant with EU health, safety and environmental legislation and objectives
- A considerable scrapping volume (capacity) is processed at non-facilitated sites on beaches rather than at dedicated facilities
- An increase in no./ tonnage of vessels requiring scrapping is predicted over a fifteen year timescale from 2001 – 2015
- The dominant component of this comes from the merchant ship fleet in which the predicted average annual volumes for Europe are:
  - 107 – 247 ships
  - 4.3 – 11.1 million dwt

  - 2.9 – 7.4 million GT
  - 0.86 – 1.48 million tonnes steel

- It is not considered practicable to upgrade the existing facilities outside Europe to achieve compliance and the concept of pre-processing within Europe (or within other OECD member states) to achieve a sterile (or neutral) ship prior to dismantling is not considered to be either economically or technically viable.
- Developments in environmental legislation and objectives within the EU are targeted to maximise the re-use and recycling of materials and to reduce and limit the disposal of waste materials by landfill or incineration. The policy of minimising waste and maximising return will also be governing for the disposal of vessels.
- There is little or no re-use market for ship components and/or structure within Europe and significant cultural and legislative obstacles exist to implement such practice. The emphasis of ship scrapping at the present time in a European context is therefore to maximise the recycling of waste materials rather than focusing on the opportunities of re-use.
- There is an economic balance between the labour cost of separation and the increased value of 'purer' waste streams. The level of separation achievable in India and other ultra low labour cost countries is not considered economically viable in Europe and the absence of local re-use markets exacerbates this situation.
- Based on projected volumes, a single, high volume, fast turnaround facility is proposed, comprising a dock large enough to serve vessels up to 400,000 dwt.
- Existing limitations on the dimensions of scrap steel impose a requirement to dismantle the main steel structure into small pieces which currently are a maximum of 1.5 x 0.5 x 0.5m in size. To achieve a fast turnaround of ships through the dock, ships will be initially divided into large 800 tonne sections for transfer to land-based open dismantling workstations or to covered workshops where the removal of toxic or hazardous materials as required will be carried out.
- A combination of thermal and mechanical cutting processes are proposed for the steel dismantling process, which is estimated to represent approximately ¾ of the total waste stream by weight.
- The remaining ¼ of the waste stream has been categorised into basic waste streams which will require recycling.

Economic issues;

- The economic analysis has demonstrated that the end-of-life value of the vessels will be heavily dependent upon the costs of separation and dismantling, such costs being in turn primarily influenced by the prime employment cost of labour.
- Additionally in undertaking the analysis, it has been necessary to assume a resale/disposal value to the anticipated waste streams. "Scrap" values in the recycling field are generally highly volatile representing commodity market prices and our economic analysis has utilised current market values. Variations in scrap values and disposal costs will of course affect the

economics of ship dismantling. The dominance of scrap steel revenues will make this particularly applicable.

- It should be noted that the productivity levels achieved in dismantling, and hence the required manning levels of the facility, will influence the overall economics. The adoption of novel applications of steel cutting technology and the assumptions regarding other dismantling labour requirements inevitably mean that the economic analysis should only be considered as a "broad-brush" indication.
- The analysis demonstrates however that projected ships end-of-life values, expressed in US$ per tonne of steel, are highly dependent upon the labour cost in the country of the dismantling facility. The example shows that a "break-even" point falls somewhere in the range of US$10 –15/hr.
- Employment costs in most Eastern European and FSU countries fall in the range US$1-5/hr whereas in Western European countries employment costs fall in $15 – 30/hr range.
- Economic viability will therefore be greatest in the lower cost economy countries of Eastern Europe and the FSU, and it is likely that the labour costs applicable within Western European countries would result in a negative ship end-of-life value**.**
- Such end-of-life values contrast with the scrapping prices paid currently to shipowners by the ship scrapping operators. These values themselves are market driven and volatile, however recent values of $125/steel tonne have been quoted and trends have shown prices in the range US$ 100-125 /steel tonne over the last few years. At such levels the current shipyard operators would seem to be able to achieve a premium to international scrap steel prices in terms of the net revenue per steel tonne achievable.

Technological and Economic Feasibility of Ship Scrapping in Europe rests upon the ability of applying efficient non-labour intensive steel processing methods in a high volume scenario. The development of furnace technologies allowing larger "scrap-batches" will reduce the required cutting volume and thereby improve the economy of the process.

2 INTRODUCTION

There is no purpose-made legislative framework covering the demolition processes of vessels as such, either in Europe or elsewhere. There are, however, various standards, norms, regulations and international conventions that may have applications or relevance within certain segments of the processes involved. These may be of occupational nature or may concern environmental matters, safety issues, aspects of health and general employment rights. Within Europe, such legislation is well developed, established and adhered to in most all sectors and mirror expectations to conformity for non-regulated industrial activities.

2.1 Recycling and sustainability

Current ship scrapping and associated vessel demolition activities represent a manufacturing industry supplying raw materials to steel industries as well as providing 2nd hand components to a wider market.

Steel production from scrap is a sustainable process in that it achieves a far better environmental performance in light of energy efficiency and the preservation of non-renewable resources in comparison with the alternative ore-based production. The energy balance between the two approaches may differ by up to 70%. However, the majority of scrap volume originating from vessels is extracted by means seriously in conflict with those principles generally valid and expected within the European community.

2.1.1 Vessel categories

Offshore fields, not only those within Europe, are decommissioned or updated by the introduction of modern production concepts at an increasing rate. Consequently, an increase in required scrapping capacity for offshore structures may be expected in a relatively short timescale.

The vast majority of merchant tonnage sold for scrapping is exported to facilities located on the Indian sub-continent. These, often larger vessels reflecting the building scenario of the 1970’s and the 1980’s, arrive at the beach-based non-facilitated sites usually by their own power.

Smaller merchant vessels, inland waterway vessels, are most often disposed off locally. Statistics indicate that this fleet segment is decreasing and hence one is lead to believe that the scrapping volume in this category is increasing.

The disarmament following the ending of the cold war and the collapse of the economy of the former USSR republics has lead to a huge increase in naval tonnage being decommissioned. However, a relatively small proportion of these has been scrapped. This may reflect a desire by states to maintain a certain military contingency. Looking at the age composition of decommissioned naval vessels, it becomes evident that disposal will be required increasingly in the near future.

2.1.2 European Environmental Context

Faced with the ever-increasing volume of waste generated by our modern consumer society, the European Community is developing a long-term strategy to reduce the amount of waste produced, and to ensure that this waste is disposed of in a manner causing least damage to the environment.

The ban amendment of the 1989 Convention on Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention) specifically prohibits the export of hazardous wastes from the Community (OECD member states) to non-OECD member states. Many of the hazardous materials to be found aboard end-of-life vessels appear in the Annex VIII and Annex IX waste lists (list A/ B) of the convention.

The European community is also looking to reduce our dependency on landfill, and is actively encouraging other methods of waste disposal such as recycling and composting, as well as incineration with energy recovery.

The volatility of the markets for recyclable materials make it difficult to maintain standards in recycling operations, as health, safety and environmental issues are often ignored or de-prioritised as a consequence of optimising profits or that of declining revenues. Most European governments have adopted legislative measures to correct this situation, using the principle of “the Polluter pays”.

Legislation has placed a duty of care on the producer of waste to ensure that a properly licensed waste disposal contractor handles the waste, in a sound environmental manner. There is a cost to the waste disposal operator in acquiring the relevant licences and maintaining the standards necessary to hold the licences. This cost is passed on the waste producer. Laws introduced in individual European countries also include a landfill tax, and a ban on certain materials from landfill, further encouraging waste producers to look at reducing or recycling waste.

These laws have enabled the recycling industry to commence charging for the handling of materials for recycling, as the waste producer has either no alternative route or a more costly waste disposal route.

2.1.3 Implications for vessel disposal and scrapping industries

The changes in regulations in the EU and the growth in environmental concerns relating to disposal were highlighted in the Brent Spar disposal of the offshore structure. This, combined with pressure from Norway and the USA, has served to highlight the concerns over the conditions under which ship scrapping currently takes place.

The ban amendment of the Basel Convention may also require the shipping industry within Europe to reconsider its approach to the scrapping of ships that have reached the end of their operational life.

Considering European legislation in other areas, notably packaging and car manufacture, there is emerging a clearly defined role and responsibility of the producer and users in the subsequent disposal of products that are manufactured.

This, combined with the EU control over the export of toxic material, could very easily change the face of ship scrapping as we see it today. At present a ship owner receives payment when he offers his ship for sale as scrap. However, if the standards for carrying out the work are raised and the by-products handled, recycled and disposed of responsibly, this could result in a situation where the ship owner may experience a considerable cost or reduced income associated to disposal. This may have a considerable impact on the economics of the shipping industry. For the naval and the offshore sector, an increase in decommissioning costs would not imply such impacts to the same extent.

2.2 Objectives and scope

Possibilities and constraints associated with the scenario of increasing vessel disposal and scrapping within Europe, the wider European Economic Area and in neighbouring countries (Eastern Europe and Russia) are assessed in light of developing a viable and sustainable industry. The project have carried out a work programme where focus has been as follows:

- Demand for scrapping capacity over a 15-year perspective
- Capability
- Commercial aspects

By identifying driving factors generating the mechanisms involved in decommissioning including both demand and capacity, a knowledge basis is established. This represents an information resource starting-point supporting the assessments necessary in order to evaluate the feasibility of undertaking ship scrapping in Europe. The context of these assessments are identified by drawing the framework to which ship scrapping should be subjected, reflecting applicable regulations and adopted and recognised practices including the aspects of safety, health and the environment. Commercial realism is assessed and implemented in project activities as applicable.

2.2.1 Methodology

A methodical strategic approach (see Figure 2-1) is adopted in order to address the study objectives.

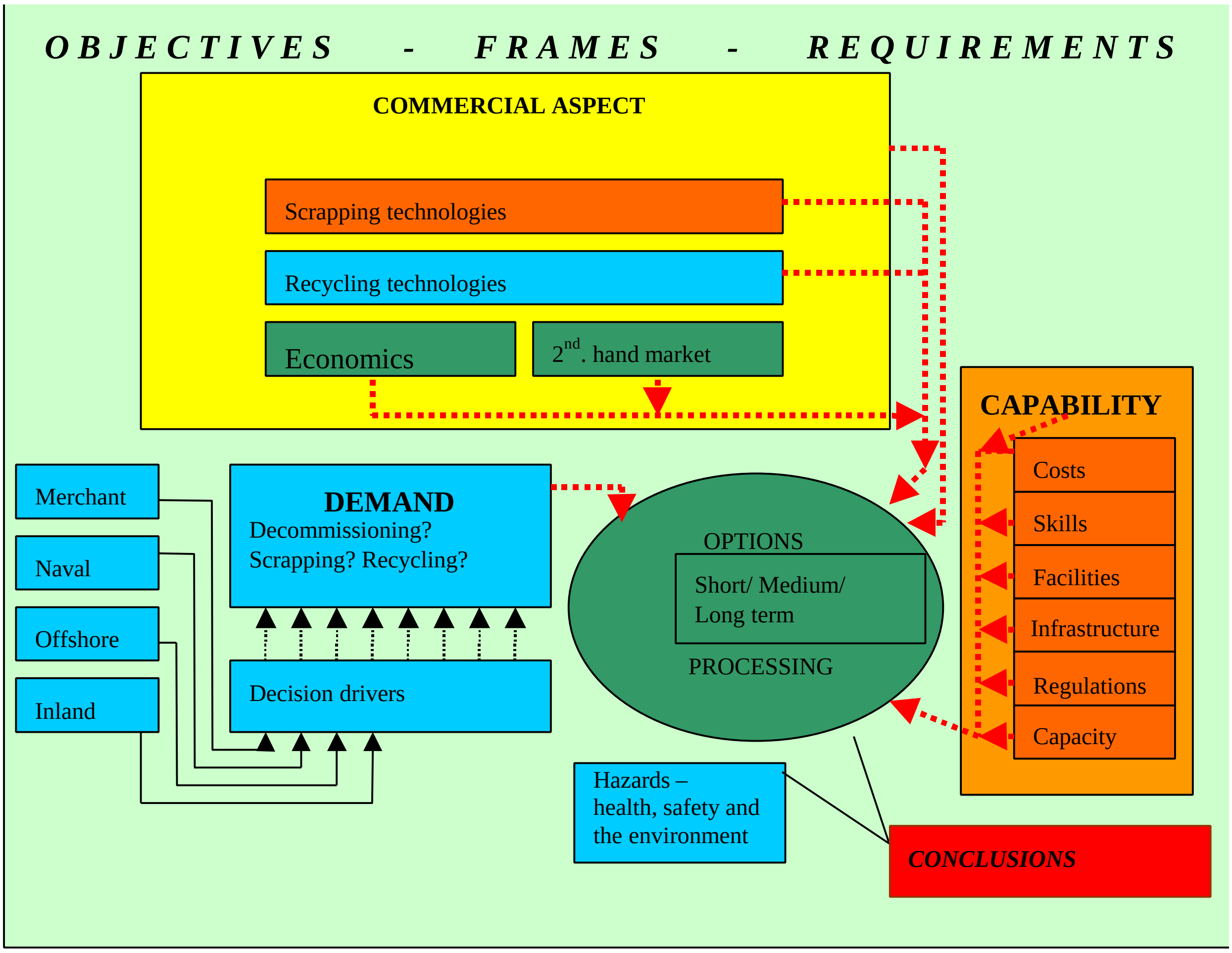


Figure 2-1 Project structure, work programmes and interrelated tasks. Colour codes refer to related subject areas.

The initial angle of the study aims to:

- Define and quantify the demand for decommissioning/ scrapping by statistics and probability prediction models forecasting a future trend over a 15-year perspective. This includes the identification of dominant decision drivers for respective vessel categories.
- Assess issues of environmental concern related to the decommissioning/ scrapping process including addressing material composition focussing on areas associated with the aspects of safety, health and the environment.
- Define and quantify ship scrapping capability and key parameters affecting this.
- Assess and provide recommendations on the technological context within which ship scrapping takes place. (Demolition/ treatment and recycling technologies).
- Address economics, the costs and revenues associated with the decommissioning process.

These are key-tasks providing insight enabling considerations on opportunities arising from the resultant demand/ supply combination and to the economic implications to be made.

Recommendations on future scrapping strategies and associated matters are based upon this approach.

2.3 Accomplishment

The study commences with an analysis of the world fleets for merchant vessels, offshore structures, naval vessels and inland waterway vessels. Characteristics and projections of demands and requirements associated with the disposal of these, once they have reached the end of their useful life, has been established. The analysis demonstrates that the dominant volume clearly emerging from the merchant vessel sector with the other three sectors representing a very small part of total demand. The merchant vessel sector is similarly dominated by the cargo vessel fleet which represent approximately 95% by deadweight. The remaining analysis has therefore concentrated on the volumes, nature and characteristics of the cargo vessels sector, which will dictate the facilities required.

The initial review of the current situation in the ship scrapping market identified that there is little or no activity currently taking place within neither European OECD member states (OECD Europe) nor the geographical Europe.

The current dominant areas for ship scrapping in the world market are India, Bangladesh, Pakistan and China. The conditions under which scrapping is undertaken in the Indian sub-continent have been studied to some detail and are considered to be non-compliant in many respects in relation to EU safety, health and environmental (SHE) legislation and objectives. The nature of this non-compliance is fundamental to the scrapping process and downstream recycling and reuse procedures, and is considered to be deeply rooted in the cultural, social and legislative environment of the countries. It may therefore be assumed that the provision of a compliant ship scrapping facility would need to be located within Europe.

Environmental objectives and legislation within the EU are increasingly focusing on re-use or recycling of materials to reduce the volume of landfill and incineration of waste as well as to preserve natural resources and in particular those being non-renewable. It is assumed in this study therefore that maximum levels of recycling or re-use will be an issue of compliance and should be prioritised. At present time, there are many social, legislative and cultural barriers to the re-use of ship’s components within the EU and there are no meaningful markets for such items unlike countries in the Indian sub-continent. Following this line of argument, it is concluded that the potential of ship scrapping in Europe must focus on recycling rather than dismantling for component reuse.

Within the recycling scenario there is an economic balance to be achieved between the cost of separation of mixed components and the increased waste stream value or recycling opportunities for ‘purer’ waste streams. Experience from recycling industries elsewhere however, indicates that such separation is generally not cost effective. It is therefore assumed that the level of separation achieved in the traditional ship scrapping countries is neither justifiable in terms of end use opportunities nor economically viable. The waste streams resulting from the demolition process have been assessed and a number of primary waste stream categories representing potential assets have been identified. These have provided as a base for the economic analysis of ship dismantling undertaken.

The amount of waste is dominated by the volumes of steel in terms of both weight and volume.

The physical characteristics of ships dictate the physical characteristics of the required facilities. To cater for the variety in ship size, facilities must also offer a level of flexibility enabling parallel as well as sequential operations of multi-type/ size vessels. Large docking facilities are required of which the main driver is the volume of the predominantly steel cargo areas of the vessels. On the basis of the projected ship scrapping volumes, it becomes clear that volume processing of steel is the dominant characteristic. Analysis has shown that a single dock facility would handle the projected annual volumes and provide the best economies of scale. Some 98% of the forecast scrapping requirement by deadweight (representing 99.9% by numbers) relates to vessels up to 400,000 dwt and the capital cost difference between this size of dock and a smaller dock is relatively small in overall terms. It has therefore been assumed that a single volume throughput facility is appropriate incorporating a dock large enough to handle vessels up to 400,000 dwt.

Market prices for waste materials in the recycling market are highly volatile reflecting the supply and demand of the commodities. It is not possible to reflect such variability within the scope of this study, and so current resale and disposal values have been assumed in order to undertake a basic economic analysis.

Assumptions have had to be made regarding the productivity of dismantling activities within such a high volume purpose developed facility. The productivity level achievable for the dismantling of the steel structure of the vessel will in particular have an influence. This study has not identified any similar facility handling the physical size and workload volume of ship scantling steels. A variety of available steel cutting technologies have therefore been assessed before concluding that a combination of thermal and mechanical cutting processes offers the best economics. Current standards in the scrap steel market limit the size of sections that will be accepted to approximately 1.5 x 0.5 x 0.5 metres which imposes an enormous workload on the facility. The steelwork cutting productivity is therefore likely to have a major impact on the overall economics of the processes. We have estimated this through theoretical analysis of cutting lengths and known process times for such. The limited size is governed by current furnace limitations. An increase in acceptable size will reduce the required workload and hence influence the economics of the facility.

In general terms, it becomes clear from the analysis that the cost of labour for manning the proposed facility is a critical factor to the end-of-life value that may be expected from the proposed approach to ship scrapping. We have therefore looked at four different labour cost scenarios, and it can be seen that break-even conditions lie in the range of $10 - $15/hour range. This would seem to confirm our initial conclusions that such a purpose built dedicated facility would be most economically located within the lower cost/ wage economies of Eastern Europe or FSU countries.

Interestingly, the economic analysis indicates that positive end-of-life values may therefore be possible in these economies where labour costs currently lie in the $1 – 5/ hour range, although this would be dependent on the basis of financing and the return on investment required. However, these must be compared with the current prices obtained by ship owners from traditional ship scrapping operators and are likely to represent a significant reduction in the end-of-life value and hence ship investment appraisal results.

3 END-OF-LIFE DECISION FACTORS

The common denominators connecting the four categories are likely to identify to what level mutual decision factors are present. In physical likeness it is obvious that the conventional vessel categories; naval, merchant and inland waterway fleets have common grounds whilst offshore structures may be seen as an outsider. When looking at respective operational regimes, it becomes equally obvious within the vessel category, that there are significant and relevant differences.

3.1 Offshore structures

An offshore field development is first and foremost governed by reservoir size, which again is indicative to both infrastructure and production life and hence expected life span of the offshore structures required. Almost all existing offshore fields in both Europe and elsewhere are developed specifically to suit a particular reservoir and a production schedule. Consequently, the decommissioning scenario is defined in terms of time. However, improvements in production techniques and methods have for some fields' lead to an increase of the original production volumes and also an expansion in the expected life of the field. Field production upgrading can occur more than once during the production phase. In the case of production upgrading, installations are assessed and modified for extended life.

The general development of reservoir production efficiency has lead to two main directions that will have influence on future decommissioning and disposal of offshore structures.:

- Procedures are to a greater extent being remotely operated and monitored allowing a reduction of scale of structures required. This has resulted in the development of sub-surface production installations.
- Reservoirs of marginal cost-benefit potential based on conventional technology have proved profitable by adopting alternative technologies. Floating production concepts are now increasingly in use. These structures are in essence ships with processing technology installations rather than conventional offshore structures. The first generation of these units was predominantly designed for a limited life span. Later developments have shown a greater flexibility allowing the unit to serve at different locations during its life and hence these are designed for a longer life.

Traditionally, decommissioning follows when the reservoir is "dry". Existing structures can to a very limited extent be re-used for its original intended purpose as its design features are specific for the field it serves. It is therefor assumed that there are no real re-use alternatives available. Consequently, decommissioning is equivalent to disposal. For "new-technology" installations, the market scenario may offer alternatives. However, these installations have only recently entered into operation. Their future disposal will not influence in the timeframe considered in this work.

The disposal of offshore installations (for the North Sea and the NorthEast Atlantic) is regulated in the OSPAR Convention of 1997 (discussed in chapter 4.2.3).

3.2 Merchant world fleet

Vessels belonging to this category can be classed as either commodity carriers (primarily carrying cargo) or non-cargo carriers. These groups can again be broken down into main types. Important main cargo carrying vessels types are; tankers, bulkers and general cargo carriers. The important types in the non-cargo-carrying group are passenger vessels and fishing vessels.

The particular characteristic of a vessel will reflect the trade to which it is designed for. Global trade relying on shipboard transport represents an enormous span in requirements resulting in a considerable number of vessels types and sub types. In some trades, the transport requirements are changing rapidly, whilst others are more settled. Changes in requirement dependent upon a trade-specific scenario may impact the economic life of a vessel in that it becomes obsolete.

New developments and technological breakthrough may also provide as a barrier in the market for ageing ships. Market preference may phase-out ageing technology and thus ageing ships. However, this again is not applicable to the same extent for all trades. Incentives such as environmental indexing schemes, i.e. as implemented in Sweden, Norway and as initiated by Green Award (the Netherlands) may develop to phase out or remove ageing tonnage more rapidly.

A stronger and more important barrier is that of regulations requiring new technology or general upgrade to be implemented. The most important regulative tool presently affecting the trading life of vessels is that of the MARPOL Convention. The phase-out mechanisms built into Annex I (Regulation 13) to the convention, limits the operational trading life of conventional built tankers by requiring major upgrading at the 5th special survey (at age of 25 years). Single skin tankers must at this stage convert to hydrostatically balanced loading or install segregated ballast tanks. Both options represent costs and extend the remaining trading life by only another 5 years. At the 6th main survey (30 years), double hull is required. Regulations also affect the trading life of bulk carriers. Following a dramatic increase in losses of such tonnage, (92 ships (1,540.443 Dwt. from 1995 – 1999) regulations now require a structural modification for ageing vessels.

Tonnage are also “naturally” deleted from the registers and scrapped simply because of old age. Repairs and maintenance required to keep up a minimum standard exceeds potential earnings, and it may be more profitable for the owner to collect the price attained by selling for scrapping.

When keeping a vessel in operation is no longer viable regardless of the cause, it is usually offered for sale to the ship breakers through shipbrokers. In some cases, “cash buyers” will take the vessel directly off the hands of the owner and re-sell for scrapping;

- Alternative 1: The shipowner may sell the ship directly to a ship breaker company, or more often through a broker. When the ship is sold to the ship breaker company, the shipowner must provide for transportation of the ship to its final destination. The ship is then sold for the “going” price in the global market.
- Alternative 2: The shipowner sells the ship to a “cash buyer” company, which again will transport the ship to the ship breaking location. The price obtained for the ship is then lower than in alternative 1.

The various shipowners may or may not have their own procedures regarding specification of hazardous materials on board, since such environmental declarations are not an international requirement yet. Ships sold for breaking in India are required to be “gas free for man entry”, resulting in cleaning costs for the shipowners. Ships that are subjected to extensive cleaning (i.e.

tankers) will therefore most likely be sold to other ship breaking nations where this is not a requirement.

Ships are purchased on the basis of contracts either prepared by the ship breakers, or more often the broker or by “cash buyers”. “SALESCRAP 87” is a standard contract format developed by BIMCO and commonly used and accepted by the scrapping industry. A new revised version of “SALESCRAP 87” is being developed and is expected to be released by the summer of 2001. The next contract format will differ significantly from the previous version and is likely to include precautions and recommendations on environmental issues.

3.3 Navy fleet

The life of a naval vessel differs from that of a civilian with basis in its basic operational purpose. This is valid also for the decision factors of importance leading to the decommissioning and later the scrapping of such tonnage.

The larger naval vessels are built to high standards at high costs for a particular strategic purpose and integrated in national and international military long-term plans. Typically, they will reach a higher age than a merchant vessel. Refits and modifications are common and for some types a nearby continuous process. The smaller naval vessels (service vessels, patrol vessels, etc) have a life pattern similar to civilian vessels.

The process leading to scrapping in this category is initiated by deciding decommissioning. For purposes of military contingency, decommissioned vessels are typically de-militarised and laid up for a long period before eventually being scrapped. The decommissioning period can last for longer than 30 years. This work has identified existing but decommissioned naval tonnage built as early as 1924.

The major military powers and strategic alliances have limited or no scrapping capability and have relied on selling naval tonnage on the open market resulting in these vessels ending their life on the beaches of the Indian sub continent. This has caused major protests among the general public in many countries. The debate has largely proven a non-acceptance of this practice. The consequence has been that the scrapping of allied naval vessels in developing countries have ceased and subsequently, the decommissioning period has been affected.

The controversy related to scrapping of military tonnage is still not resolved. In the US, the policy has now changed and plans are laid based on disposing the vessels nationally. However, the capacity and the economics of this are still unresolved issues. The growing numbers of laid up former USSR military tonnage also represent an unresolved disposal challenge.

3.4 Inland fleet

Inland waterway vessels are by characteristics small and represent a diversity in type serving in sheltered waters.

The fleet’s average age is considerably higher than that for the merchant fleet. Statistics indicate further that this transport alternative is losing in the battle against transport by road and rail. Consequently, the number of vessels have decreased, new building activity is very low and consequently, the average age will continue to increase.

The main decision factor related to decommissioning and scrapping is that of profitability. As rates are squeezed in competition and cost of repairs and maintenance increases as age takes its toll, the owner may choose to sell the vessel for scrapping.

The inland fleet will not compare in unit prices seen when scrapping merchant tonnage. Further, these vessels are incapable of undertaking open ocean voyages and thus must be scrapped locally or regionally.

The process following the decision to sell for scrapping will largely follow that for the merchant fleet.

4 DECOMMISSIONING VOLUME

The four categories;

I:	Offshore structures	II:	Merchant world fleet
II:	Navy fleet	IV:	Inland waterway fleet

have been assessed with emphasis on fleet size, age composition, growth/ decline characteristics and other parameters that may influence the patterns of decommissioning for disposal. Decision factors (chapter 3) have been an input to the volumes and the forecast produced.

Detailed global registers for all categories have been established and analysed. Future decommissioning and consequently scrapping prognoses of expected supply of tonnage available to the recycling markets over a 15 year perspective have been established. For purposes of practicalities, forecasts have been extrapolated to cover the life of a vessel of respective category from year 2000 through to estimated retirement. The latter stage of the presented prognoses, i.e. after year 2015, is exposed to coarse assumptions.

Findings are discussed and presented focussing on the source of supply by categories and on characteristics that may influence the technical and economical dimensions involved.

4.1 The European dimension

A comprehensive share of the world fleet of vessels is under the control of European owners or registered under European registries. An even larger share of the world fleet will at some stage have had some other European connection. This may encompass such as nationality of manufacturer, operator or area of trade.

The feasibility of decommissioning a vessel in Europe will not depend upon its European connections alone but may reflect factors such as national and international policies and regulations but also issues of a practical nature such as size and distance to markets.

Compliance to the concept of sustainable operations includes all aspects in a life cycle, hence including both the production and disposal stages. This is reflected in recent directives of the European Commission placing a greater obligation on manufacturers/ distributors of goods to ensure that the products they produce are not only disposed of in a correct manner but also recycled to a higher degree. This may be illustrated by**;**

- **The Packaging Waste Directive** obliging producers, fillers and retailers of packaging materials, to recycle a percentage of all packaging that they handle (entered into force in 1999).
- **The Directive on Waste from Electrical and Electronic Equipment**, obligating producers to similarly ensure that a percentage of the products are recycled after end of life (expected to enter into force in 2001)
- **The Producer Responsibility for End of Life Vehicles,** currently under discussion and likely to become law in 2001 or 2002. This will oblige manufacturers of motor vehicles to ensure proper disposal and recycling when vehicles are no longer roadworthy.

The implications of legislation requiring the original producer to assume responsibility for disposal would be onerous on European countries, if retrospectively applied in shipbuilding, in view of their historical dominance in vessel construction.

The stronger emphasis on minimising consumption (in particular of non-renewable resources) has increased consciousness in most all sectors of industry, shipping being one of few exceptions, on methods of optimising the share of return-to-life following end-of life. The *dispose of* scenario is increasingly moving away from that of re-use to increased recycling. Future ship scrapping in Europe will be expected to perform similarly to industry in general and is hence subjected to the same expectations. As seen in the car manufacturing industry, this may impose changes to the current design and construction practices within shipbuilding.

4.1.1 The Basel Convention impact

The process of decommissioning for scrapping and re-use/ recycling introduces a number of aspects, also of a legal nature, to be considered. The transboundary nature of the activity calls for some form of international compliance. However, at present there are no purpose-made legal instruments in place that addresses the topic of decommissioning, demolition and recycling of mobile structures.

There are International conventions/ regulations with associations to elements of the process. The most important of these are listed below;

- The 1989 Convention on Transboundary Movements of Hazardous Wastes and their Disposal (The Basel Convention)
- 1972 London Dumping Convention (1996 Protocol)
- OSPAR convention of 1997
- The 1993 Council Regulation (EEC) No. 259/93 on the Supervision and Control of Shipments of Waste within, into and out of the European Community (Shipment Regulation)

That of most interest, The Basel Convention, prohibits the export of hazardous wastes and other wastes to other states without the prior approval from the importing state. The exporting state shall not permit such export to states, which have prohibited the import of such wastes or without a consent obtained by the importing state. But more important, the Basel Convention has prohibited the transboundary movements of waste from OECD countries to non-OECD countries destined for final disposal, and phasing out of wastes destined for recycling or recovery operations.

The natural market for ship scrapping in Europe reflecting the spirit of the Basel Convention has provided the following definition;

European market; All European vessels, that is all those of European geographical nationality of registration, and also provided OECD membership. The merchant fleets of OECD states outside Europe (Australia, Canada, Korea, New Zealand, Japan, Mexico and USA) contribute in a lesser scale and are hence excluded here.

This definition is required for assessing the volumes of scrapping candidates arriving from the merchant world fleet. The definition may also be used for inland waterway vessels. The volumes likely to arrive from the naval and offshore sector are governed by different parameters as discussed in chapter 3 and accounted for in the following.

4.2 Offshore structures

4.2.1 World-wide

There are more than 6,500 offshore installations comprising a variety of structures world-wide. Some 4000 are located in the Gulf of Mexico (Figure 4-1). Approximately 490 platforms are situated in the North Sea and the North East Atlantic. Of the latter, around two-thirds are considered small structures operating in shallow waters (less than 75 meters depth) or weighing less than 4000 tonnes. The remaining are those comprising large steel structures or large concrete gravity based structures.

A typical platform consists of ”topsides” (weighing up to 40,000 tonnes) and a supporting substructure, the ”jacket”. In general, one may claim that the topsides represent the potential as a carrier of hazardous substances, whereas the substructure consists of clean steel or concrete (ref.: /6/). Offshore structures are one-off designs for a specific field and hence differ in characteristics accordingly.

A significant number of European offshore oil and gas installations are entering their last operational phase and expected ready for decommissioning within the next decade.

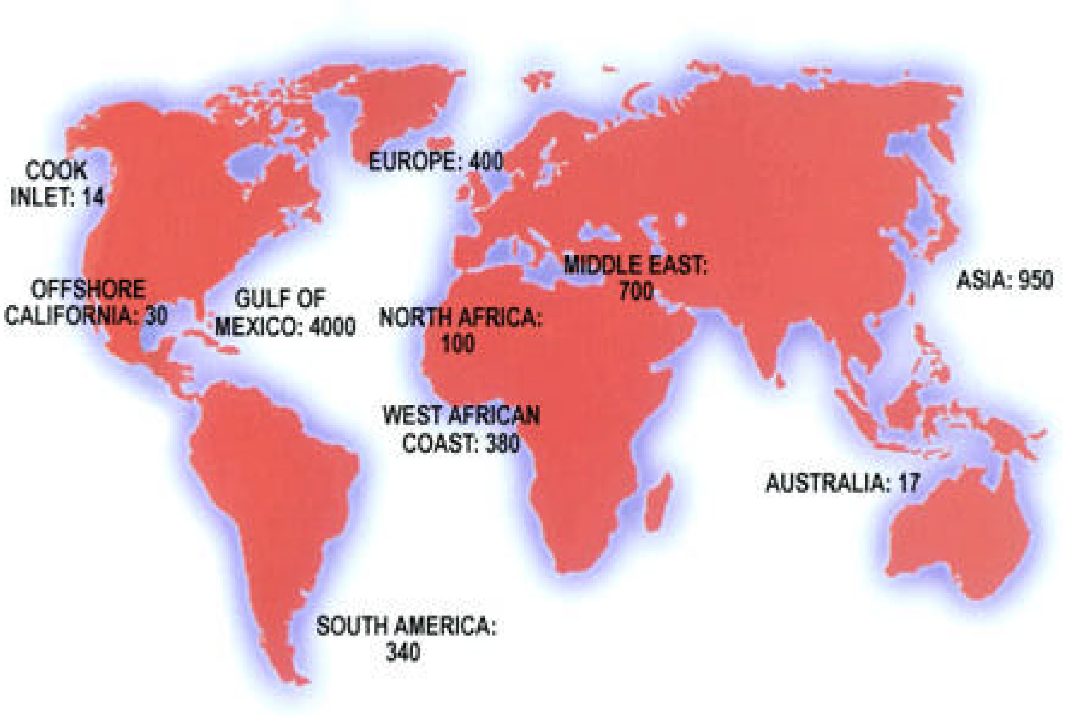


Figure 4-1 Offshore oil and gas installations world-wide (ref.: /7/)

4.2.2 Europe

The number of European offshore oil and gas installations varies from 400 to 609 depending on source. This relatively large gap reflects non-compliance in definitions used in the different statistical sources (i.e. reference year, geographical definition of Europe, types of offshore structures). Previous work undertaken on behalf of the European Commission (ref.:/1/) is used as a main source in the following predictions.

Table 4-1 presents the distribution of offshore structures in Europe. It should be noted that the data presented does not include mobile drilling ships nor flotels. Certain types of offshore ships/ vessels are also included in the merchant fleet registers, hence there may be some overlap and hence inconsistency in the data.

Table 4-1 Distribution of type of offshore structure (ref. /1/).

Country	Number of structures per type							Grand total
	CFPF	FPF	FPSO	JU	TLP	GBS	Steel structures	
Denmark	0	0	0	0	0	0	39	39
Germany	0	0	0	0	0	2	0	2
Greece	0	0	0	0	0	0	4	4
The Netherlands	0	0	0	4	0	2	114	120
Ireland	0	0	0	0	0	0	2	2
Italy	0	0	0	0	0	0	112	112
Norway	1	5	3	2	2	14	54	81
Spain	0	0	0	0	0	0	2	2
UK	0	6	10	5	1	10	215	247
Grand total	**1**	**11**	**13**	**11**	**3**	**28**	**542**	**609**

CFPF: Concrete floating production facility
FPF: Floating production facility
FPSO: Floating production storage and offtake
JU: Jack-up
TLP: Tension leg platform
GBS: Gravity based structure

A total of 89 % of all installations are of piled steel structures. The average total weight of such piled steel structures (excluding piles) has been estimated to be 7,282 tonnes. The total weight of all steel structures will be in the order of 3,9 million tonnes (ref. /1/).

4.2.3 Offshore decommissioning and disposal regulations

The OSPAR convention of 1997 regulates the disposal at sea of offshore installations in the North Sea and the North East Atlantic. Permits for partial removal or disposal at sea are issued on a case-by-case basis by the individual national authorities. Topsides including systems and components are brought to shore for reuse or recycling. Reinforced concrete structures are heavy and difficult to break up. These structures are for practical reasons not considered recyclable. Assessments considering the final fate of these are likely to recommend them left in place or disposed of at a deepwater disposal sites. Several studies have concluded that clean steel or concrete can be disposed of at sea with negligible environmental impact (ref.: /6/).

The technology required to move offshore installations to shore for recycling and reuse already exists. However, potential impact in relation to the aspects of health, safety and environmental as well as costs need to be considered in the process of determining the fate of the individual structure (ref.: /6/).

4.2.4 European scrapping forecast

An estimation of the number of offshore fields in Europe to be closed down for the years 1985-2066 is presented in Figure 4-2. These numbers are based on the expected production time for the various offshore production fields in Europe.

By year 2000, approximately 90 fields are assumed closed down. In the next 15-year period (2000-2015), another 160 fields are expected to be closed down. It should be noted that improved oil production technologies have expanded operational life of several fields. This development may impact the predictions presented here.

Installations are decommissioned in the sense that their operational life has ceased but they are not necessarily scrapped or recycled. A lag period of 2-20 years from closedown or decommissioning to actual scrapping may be expected. Some of the structures may not be scrapped at all (see chapter 6).

The long lag-period between closedown and scrapping is evidenced by the fact that only very few structures have been scrapped (or fully decommissioned) until now. This may also reflect the potential of alternatives to scrapping (recycling/ resale). The predictions of the potential scrapping volume for the next 15 years (presented in Figure 4-2) are based on estimated closedown frequency for the period 2000-2015 only and do not take account of the potential build-up of structures due to the long lag-periods nor the effects of suggested alternative use.

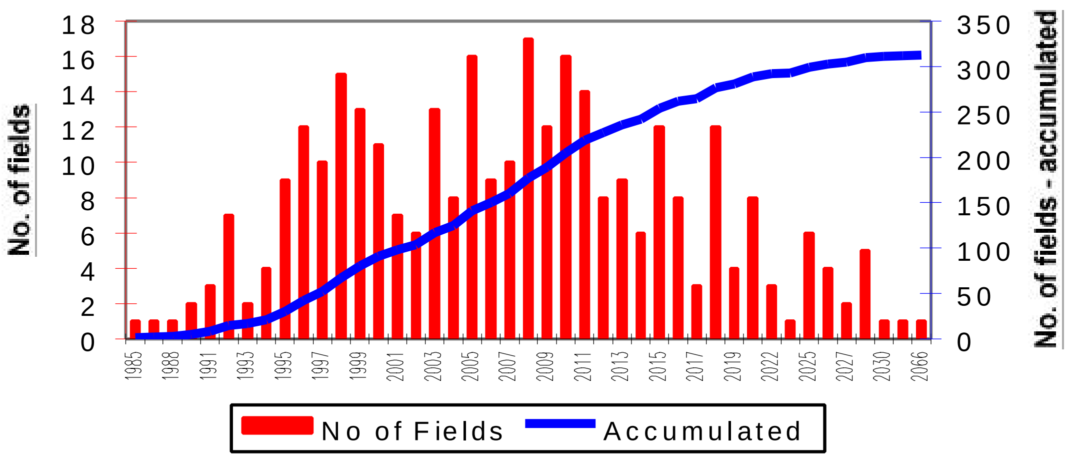


Figure 4-2 Time of closure for European offshore fields (ref.:/1/)

4.2.4.1 Input to the recycling process

The number of structures per field varies from 1 to 20. European offshore production fields have an average of 1.1 structures per field (ref. /1/), the larger fields consisting of typically 5 structures.

The volume of steel offshore structures (production installations only) to be considered for decommissioning in the next 15 years can be estimated as follows:

$$W_T \approx W_A \cdot S \cdot F \qquad (4.1)$$

Where:

W_T: Total weight of all steel structures (tonnes)

W_A: Average total weight of a steel structure (tonnes)

S: Average number of structures per field

F: Number of fields to be closed down

Based on a total number of 160 fields to be closed down in the period with an average of 1.1 structures per field, each containing 7,300 tonnes of steel, some 1,150,000 tonnes of steel may be recovered. (Note that 89% of structures are of steel construction).

Based on this, the annual scrapping rate in Europe would be about 80,000 tonnes of steel structures arriving from the offshore sector. However, this represents a coarse estimation due to the considerable uncertainties in lag periods and alternatives to scrapping.

4.2.5 Conclusion

The number of European offshore oil and gas installations varies from 400 to 609 depending on the source used. This large gap is probably caused by differences in the reference year, the geographical definition of Europe and types of offshore installations included in the statistics.

Assuming a closedown of 90 fields by year 2000 and taking into account the fact that very few already decommissioned structures have been scrapped, a backlog of structures representing some 6 units annually (39,000 tons of steel structures/ year) can be expected. Over a 15 year period this will represent 585,000 tons of steel structures.

In addition, over the next 15-year period, another 160 fields are expected closed. If this is assumed arriving at a constant rate and scrapped without delay, some additional 80,000 tons of steel will arrive annually from this category. The yearly scrapping potential of European offshore structures is summarised in Table 4-2 (approximated numbers).

Table 4-2 Yearly scrapping potential for European offshore steel structures in the period 2001-2015

	No. of structures	**Tons**
Backlog by the year 2000	5.3	40,000
Closedown 2001-2015	10.4	80,000
Yearly scrapping potential	15.7	120,000

The final fate of offshore structures is not necessarily that of being scrapped. The figures presented here do not account for alternative usage.

4.3 Merchant world fleet

The world fleet of propelled sea-going merchant vessels larger than 100 gross tons (GT) reached a number of 86,817 units representing a total of 543.6 million GT in 1999. The average age of the fleet was 20 years (ref.:/12/). There are two main categories of merchant vessels:

- cargo carriers (cargo carrying fleet)

- other vessels (miscellaneous vessels)

Both are experiencing a continuous growth reflecting the global trade growth. The world fleet growth and distribution by numbers and tonnage as a function of type over the period from 1994 to 1998 is presented in Appendix A.

4.3.1 The cargo carrying fleet

The volume of ships being scrapped is dominated by the cargo carrying segment counting some 46,002 units of an accumulated tonnage of 777.8 million DWT or 515.4 million GT (1999, ref.: /12/). This represents only some 50% of the world fleet by numbers but account for as much as 95 % of the total world tonnage (GT). The importance of this category in context of being a supplier to ship demolition and recycling is overwhelming compared to the non-cargo carriers and hence, the latter category will not be addressed in particular in the following.

The average age of the cargo carrying fleet is 18 years (1999). General cargo vessels are dominant by numbers whilst the bulk carriers and crude oil tankers represent the main tonnage contributors (accounting for approximately 63 % of the total cargo carrying fleet).

4.3.1.1 Flag state distribution

For the period from 1994 to 1998, approximately 40% of vessels by number representing some 30% of the tonnage (GT) was of OECD member state origin. The OECD contribution trend over the period shows a decline in both numbers and volume (GT) with few exceptions (Norway, the Netherlands, Korea and the USA).

The dominating flag states within the OECD with reference to size (in descending order) are; Greece, Norway, Japan, UK and the USA. In Appendix B, the OECD distribution for the period is detailed. The changes in flag state distribution is however not considered significant.

By assessing the flag distribution of vessels reported scrapped in 1999, a distribution by flag state can be provided. For the purpose of identifying tonnage for input to European scrapping facilities, this has been done for geographical Europe (GEUR) and for the European OECD member states. (OEUR), see Table 4-3.

Table 4-3 European registered vessels reported scrapped in 1999

	Ships	**DWT**	**GRT**	**Share by**		
Total	630	17,303,964	10,256,797	**Ships (no.)**	**DWT**	**GRT**
GEUR*	186	6,146,516	3,554,791	30%	36%	35%
OEUR**	84	2,404,184	1,348,261	13%	14%	13%

* Geographical Europe

** European flag registers within the OECD area. Distribution used in forecasted predictions.

The largest flag registers within geographical Europe (GEUR) are Cyprus and Malta.

4.3.2 Scrapping supply, merchant world fleet

Traditional shipping represented by the merchant world fleet is by far the largest of the vessel categories considered in this work and thereby the most significant as an input to the scrapping and recovery industries.

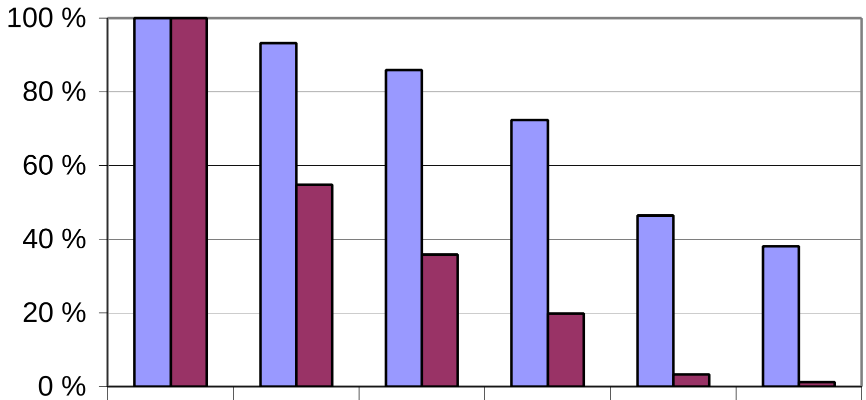
In 1999, a number of 664 vessels representing 9,9 million GT with an average age of 25 years were deleted from merchant fleet registers (ref.:/12/). Of these, 538 were reported scrapped, a number of 19 vessels were scrapped following casualty incidents, whilst 107 vessels were lost at sea. The vast majority of vessels scrapped was from the cargo carrying segment.

A number of 629 vessels representing 17.3 million DWT are registered scrapped in 1999 (ref. /10/). The deviation between the two sources to may arrive due to inconsistency in data, reporting routines or reflect a backlog of vessels awaiting scrapping following decommissioning.

Statistics for 1999 on tonnage sold for scrapping is at a record high at 30 million DWT (ref.: /23/), see chapter 4.3.4). The inconsistency between volume sold for scrapping, that deleted from merchant registers and finally that reported actually scrapped, is considerable. This strengthens the suggestion that some tonnage sold for scrapping are not actually scrapped nor deleted from the registers but laid up or in some form of intermediate use. The high freight rates experienced in particular in the tanker segments in year 2000 are most likely a factor prolonging the trading phase.

The scrapping volume has been predicted (ref.: /19/) to remain at a high level for a period of up to 3-5 years (2000-2003/ 2005). The considerable distance between tonnage actually scrapped and that sold for scrapping and future predictions on scrapping demand may cause an aggregated backlog build-up. This may suggest insufficient scrapping capacity.

The distribution of vessels by size scrapped in 1999 is presented in Figure 4-3. Only 7% by numbers were larger than 100,000 DWT but representing as much as 45% of the total DWT. Likewise, 38% of vessels that were scrapped, were small, of less than 5,000 DWT, representing only 1% of the total tonnage. The figures demonstrate that the large number of smaller ships constitutes only a small percentage of the total tonnage and hence recyclable material. The significance of the larger vessels dominated by tankers and bulk carriers as the main source of supply to the scrapping industries is obvious.



	<400000 DWT	<100000 DWT	<50000 DWT	<25000 DWT	<10000 DWT	<5000 DWT
No of vessels	100 %	93 %	86 %	72 %	46 %	38 %
Sum DWT	100 %	55 %	36 %	20 %	3 %	1 %

Figure 4-3 Number of vessels and associated DWT scrapped in 1999 categorised by size (ref.: /10/).

4.3.3 Europe 1999

The demolition database (ref.: /10/) for 1999, provides an overview of scrapping countries demolishing European ships (by flag register). Based on average DWT it seems that the largest European ships were scrapped in Pakistan (100,504 DWT) and Bangladesh (84,609 DWT), whereas India had the largest turnover in numbers of European ships (89 ships).

Table 4-4, supported by Figure 4-4 illustrates the distribution of scrapping of European tonnage in 1999. European tonnage scrapped in Bangladesh, India and Pakistan accounted for 90% of the total scrapping volume from European registers. Turkey and Spain represented the leading European scrapping nations, although only 5 % of European tonnage (in terms of DWT) where scrapped in these countries. In terms of numbers, 26 % of European vessels were scrapped in Europe in 1999. The majority of these vessels where small and scrapped by random in brownfield facilities by opportunity.

Table 4-4 Breaker countries for European ships (European flagged – geographically) – no. of ships, DWT, GT and average DWT of ships scrapped for each breaker country.

Breaker Country	No.	DWT	GT	Average DWT
BANGLADESH	13	1099915	586633	84609
CHINA	3	162794	89814	54265
INDIA	89	2946300	1812492	33104
PAKISTAN	15	1507563	776157	100504
BRAZIL	1	4887	3384	4887
EGYPT	1	4810	9511	4810
LATVIA	1	305	452	305
OECD countries:				
MEXICO *	2	60084	37827	30042
PUERTO RICO	1	7309	5985	7309
AZORES	1	420	396	420
BELGIUM *	5	6838	6879	1368
DENMARK *	2	1745	10565	873
ITALY *	1	850	493	850
NETHERLANDS *	3	3899	0	1300
NORWAY *	3	1231	964	410
SPAIN *	14	63247	39689	4518
CANARY ISLANDS	1	0	327	0
TURKEY *	16	269546	176519	16847
UNITED KINGDOM *	1	835	814	835
UNKNOWN	14	5073	3740	362
Total EUR scrapped 1999	**187**	**6147651**	**3562641**	**32875**

Vessels above 100 GT.
* OECD countries

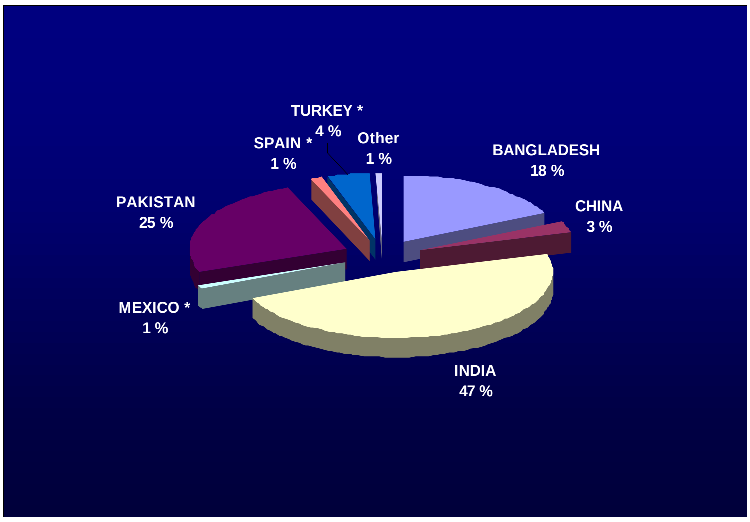


Figure 4-4 Breaker countries for European ships 1999 distributed by DWT (* indicates OECD country).

A total of 66 % of European ships (above 100 GT) by numbers scrapped in 1999 were scrapped in non-OECD countries. This represents 93 % in terms of DWT. The potential volume for increased European scrapping and recycling is represented by these figures when reflecting upon the intentions of the export ban represented by the Basel Convention.

4.3.4 Vessels sold for scrapping 1992-2000

Statistical data on vessels sold for scrapping in the last decade is presented in Table 4-5. Bulkers and tankers are dominant in terms of tonnage (DWT). The data has some fluctuation mirroring instability in respective markets. It should be noted that average age of vessels sold for scrapping has increased over the past decade.

Table 4-5 The number, tonnage and average age of vessels sold for scrapping 1992-2000* (Vessels of size >10,000 DWT only, ref.: /23/).

Year	No., DWT and Age	Tankers	Bulk Carriers	Combos	Gas vessels	Other dry	All Vessels
1992	No.	94	67	11	4	64	240
	10^6 DWT	10.22	3.913	1.296	0.011	0.775	16.215
	Age	23.8	23.6	20.8	26.8	24.7	23.9
1993	No.	110	50	15	10	129	314
	10^6 DWT	10.685	2.557	2.27	0.111	1.398	17.021
	Age	23.1	24.2	21.9	24.9	29.4	25.9
1994	No.	87	70	18	7	112	294
	10^6 DWT	12.558	4.351	2.421	0.018	1.234	20.6
	Age	22.6	24	21.9	26.3	26.5	24.5
1995	No.	93	33	9	1	91	227
	10^6 DWT	10.794	2.093	1.229	0.002	1.195	15.313
	Age	25.2	25.2	22.4	30	27.2	25.9
1996	No.	72	128	15	5	168	388
	10^6 DWT	6.829	7.297	1.904	0.021	1.967	18.018
	Age	25.3	25	23.1	27.9	27.2	26
1997	No.	40	161	6	6	187	400
	10^6 DWT	3.611	7.707	0.746	0.075	2.596	14.735
	Age	28.3	25.5	23.6	28.4	26.5	26.3
1998	No.	52	236	10	6	191	495
	10^6 DWT	7.547	11.666	1.416	0.028	3.181	23.838
	Age	25	25	22.8	27.5	25.5	25.2
1999	No.	113	194	9	6	226	548
	10^6 DWT	17.114	9.385	1.13	0.019	3.185	30.833
	Age	24.9	24.9	24.3	31.4	25.2	25.1
2000*	No.	55	29	4	1	45	134
	10^6 DWT	7.234	1.353	0.393	0.018	0.641	9.639
	Age	26.1	27.1	25	31.7	25.7	26.2
Average 1992-1999	No.	83	117	12	6	146	**363**
	10^6 DWT	9.92	6.12	1.55	0.04	1.94	**19.57**
	Age**	24.4	24.8	22.4	26.9	26.3	**25.3**

* Jan-Mar 2000
** DWT weight Age

Annual scrapping rates in terms of DWT is presented in Table 4-6. The average rate for the period was at 2.7 %.

Table 4-6 Yearly scrapping rate (by tonnage).

Year	Current fleet* (million DWT)	Scrapped** (million DWT)	Scrapped (%)
1994	704.0	20.6	2.9
1995	717.5	15.3	2.1
1996	739.7	18.0	2.4
1997	757.8	14.7	1.9
1998	765.8	23.8	3.1
1999	777.8	30.8	4.0
Average	***743.8***	***20.5***	***2.7***

* Lloyd's 1999

** Sold for scrapping, > 10,000 DWT (ref.: /23/)

4.3.5 Forecast - world merchant fleet scrapping rate

Figure 4-5 presents a forecast of expected deleted tonnage from the world fleet of cargo carrying vessels equal to or above 10,000 DWT for different period intervals. The scrapping forecast of vessels of size less than 10,000 DWT has been developed based on the assumption that fleet distribution follows the same patterns as that for vessels above 10,000 DWT. The base for the smaller category has been actual scrapping statistics for 1999. Predictions are detailed in Table 4-7 and Table 4-8, and data supporting the predictions is included in Appendix A.

By assuming an average annual scrapping rate of 2.7 % (Table 4-6), and extrapolating the world fleet tonnage from year 2000 (ref.: /12/), an "expected" scrapping volume accounting for the growth in world fleet has been estimated. Further, by assuming the vessel type distribution (for scrapping) to be consistent with that of 1999, the forecast can distinguish between types. The predictions assume a steady global economic growth and that the demand for shipping services will follow general economic growth.

The historical average scrapping rate of approximately 400 vessels/ year and 20 million DWT/year (ref. Table 4-5) is approximately 25 % below the forecasted values. The predicted scrapping volume suggests some 26 million DWT/ year. The predictions do not include the probability of longer lifetime for tankers (i.e. cease of the phase-out effect generated by MARPOL, Annex I, regulation 13). However, the majority of tankers built after 1993 are that of double hull, hence the effect of this will not influence predictions for the period of year 2000–2015. Incidents such as the Erika disaster of the coast of France in December of 1999, may however trigger regional or international initiatives that may impact the life-span pattern of large oil carrying vessels.

Further, the forecast does not include tonnage lost at sea, and may therefore represent an overestimate. Based on statistics, one may expect losses to account for approximately 3% of scrapped tonnage (or 18% by numbers). Hence, the average size of vessels lost at sea are smaller than that scrapped (ref. /11/). This corresponds with casualty statistics showing a significant representation of fishing vessels and general cargo vessels.

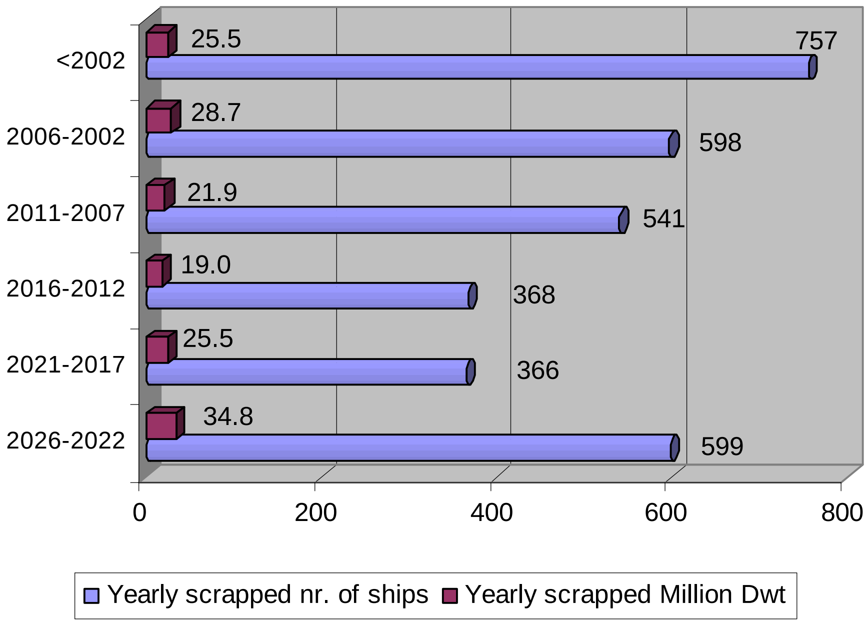


Figure 4-5 Forecast of the number of vessels scrapped yearly in different time periods with the corresponding scrapped tonnage (DWT).

Table 4-7 Forecasted global ship scrapping volume by category in a 15 year perspective (vessels above 10,000 DWT)

Year	Million DWT	No.	Tanker No./ million DWT	Bulker No./ million DWT	Dry cargo No./ million DWT	Combos No./ million DWT	Gas No./ million DWT
2001	25.5	757	199/ 13	227/ 7.9	303/ 2.55	23/ 2.04	8/ -
2002	25.5	757	199/ 13	227/ 7.9	303/ 2.55	23/ 2.04	8/ -
2003	28.7	598	155/ 14.6	179/ 8.9	240/ 2.9	18/ 2.3	6/ -
2004	28.7	598	155/ 14.6	179/ 8.9	240/ 2.9	18/ 2.3	6/ -
2005	28.7	598	155/ 14.6	179/ 8.9	240/ 2.9	18/ 2.3	6/ -
2006	28.7	598	155/ 14.6	179/ 8.9	240/ 2.9	18/ 2.3	6/ -
2007	21.9	541	141/ 11.2	163/ 6.8	216/ 2.2	16/ 1.7	5/ -
2008	21.9	541	141/ 11.2	163/ 6.8	216/ 2.2	16/ 1.7	5/ -
2009	21.9	541	141/ 11.2	163/ 6.8	216/ 2.2	16/ 1.7	5/ -
2010	21.9	541	141/ 11.2	163/ 6.8	216/ 2.2	16/ 1.7	5/ -
2011	21.9	541	141/ 11.2	163/ 6.8	216/ 2.2	16/ 1.7	5/ -
2012	19	368	96/ 9.7	110/ 5.9	147/ 1.9	11/ 1.5	4/ -
2013	19	368	96/ 9.7	110/ 5.9	147/ 1.9	11/ 1.5	4/ -
2014	19	368	96/ 9.7	110/ 5.9	147/ 1.9	11/ 1.5	4/ -
2015	19	368	96/ 9.7	110/ 5.9	147/ 1.9	11/ 1.5	4/ -
Av.	*25.3*	*579*	*151/ 12.9*	*174/ 7.9*	*232/ 2.5*	*17/ 2.0*	*6/ -*

Table 4-8 Forecasted global ship scrapping volume by category in a 15 year perspective (vessels below 10,000 DWT)

Year	Million DWT	No.	Tanker No./ million DWT	Bulker No./ million DWT	Dry cargo No./ million DWT
2001	6.0	503	50/ 1.2	126/ 1.6	392/ 3.2
2002	6,0	503	50/ 1.2	126/ 1.6	392/ 3.2
2003	6.8	397	40/ 1.4	99/ 1.8	258/ 3.6
2004	6.8	397	40/ 1.4	99/ 1.8	258/ 3.6
2005	6.8	397	40/ 1.4	99/ 1.8	258/ 3.6
2006	6.8	397	40/ 1.4	99/ 1.8	258/ 3.6
2007	5.2	359	36/ 1.0	90/ 1.4	233/ 2.8
2008	5.2	359	36/ 1.0	90/ 1.4	233/ 2.8
2009	5.2	359	36/ 1.0	90/ 1.4	233/ 2.8
2010	5.2	359	36/ 1.0	90/ 1.4	233/ 2.8
2011	5.2	359	36/ 1.0	90/ 1.4	233/ 2.8
2012	4.5	244	24/ 0.9	61/ 1.2	159/ 2.43
2013	4.5	244	24/ 0.9	61/ 1.2	159/ 2.43
2014	4.5	244	24/ 0.9	61/ 1.2	159/ 2.43
2015	4.5	244	24/ 0.9	61/ 1.2	159/ 2.43
Av.	*5.5*	*358*	*36 /1.1*	*89/ 1.4*	*233/ 3*

From DNV's registers, a relationship between lightship weight (LIGW) and DWT is found and used to produce type specific LIGW for OEUR (and GEUR) vessels requiring scrapping in a 15-year perspective from year 2000. The results are presented in Table 4-9 and Table 4-10.

4.3.6 Conclusion

From the discussion above, it may be concluded that:

- The average scrapping age of cargo vessels is approximately 26 years.
- The main scrapping contributors in tonnage are bulkers and tankers. The main scrapping countries are Bangladesh, India, Pakistan and China.
- Double hull requirements may cause longer lifetimes of cargo vessels (tankers). However, incidents may influence regional legislations and hence counteract this trend.
- The annual expected scrapping rate world-wide is about 500 vessels/year at 25 million DWT depending on fleet development, and age and size distribution.
- 66 % of the number of European ships scrapped in 1999 was scrapped in non-OECD countries. This represents some 93 % in terms of dead weight.

The input to future European scrapping facilities arriving from the fleet of merchant vessels based upon the intentions of the Basel Convention, will be represented by the vessels under European OECD flag. The remaining OECD fleet may sequentially also represent such input. The remaining OECD fleet (that of; Australia, Canada, Japan, Korea, Mexico and USA) will represent an additional 10 % by DWT.

Table 4-9 OEUR vessels above 10,000 DWT (GEUR in brackets)

				LIGW (million tons)				
Year	**No.**	**Million DWT**	**Million GT**	**Tanker**	**Bulker**	**Dry cargo**	**Combos**	**Gas**
2001	98 (227)	3.6 (9.3)	1.9 (5.12)	0.35 (0.89)	0.22 (0.56)	0.09 (0.23)	0.06 (0.15)	-
2002	98 (227)	3.6 (9.3)	1.9 (5.12)	0.35 (0.89)	0.22 (0.56)	0.09 (0.23)	0.06 (0.15)	-
2003	84 (179)	4.0 (10.33)	2.16 (5.81)	0.39 (1.0)	0.25 (0.64)	0.1 (0.26)	0.07 (0.17)	-
2004	84 (179)	4.0 (10.33)	2.16 (5.81)	0.39 (1.0)	0.25 (0.64)	0.1 (0.26)	0.07 (0.17)	-
2005	84 (179)	4.0 (10.33)	2.16 (5.81)	0.39 (1.0)	0.25 (0.64)	0.1 (0.26)	0.07 (0.17)	-
2006	84 (179)	4.0 (10.33)	2.16 (5.81)	0.39 (1.0)	0.25 (0.64)	0.1 (0.26)	0.07 (0.17)	-
2007	70 (159)	3.07 (7.88)	1.65 (4.44)	0.30 (0.77)	0.19 (0.49)	0.08 (0.20)	0.05 ((0.12)	-
2008	70 (159)	3.07 (7.88)	1.65 (4.44)	0.30 (0.77)	0.19 (0.49)	0.08 (0.20)	0.05 ((0.12)	-
2009	70 (159)	3.07 (7.88)	1.65 (4.44)	0.30 (0.77)	0.19 (0.49)	0.08 (0.20)	0.05 ((0.12)	-
2010	70 (159)	3.07 (7.88)	1.65 (4.44)	0.30 (0.77)	0.19 (0.49)	0.08 (0.20)	0.05 ((0.12)	-
2011	70 (159)	3.07 (7.88)	1.65 (4.44)	0.30 (0.77)	0.19 (0.49)	0.08 (0.20)	0.05 ((0.12)	-
2012	48 (110)	2.66 (6.84)	1.43 (3.85)	0.26 (0.66)	0.17 (0.42)	0.067 (0.17)	0.04 (0.11)	-
2013	48 (110)	2.66 (6.84)	1.43 (3.85)	0.26 (0.66)	0.17 (0.42)	0.067 (0.17)	0.04 (0.11)	-
2014	48 (110)	2.66 (6.84)	1.43 (3.85)	0.26 (0.66)	0.17 (0.42)	0.067 (0.17)	0.04 (0.11)	-
2015	48 (110)	2.66 (6.84)	1.43 (3.85)	0.26 (0.66)	0.17 (0.42)	0.067 (0.17)	0.04 (0.11)	-
Av.	*75 (174)*	*3.54 (9.11)*	*1.90 (5.09)*	*0.34 (0.88)*	*0.22 (0.57)*	*0.087 (0.22)*	*0.06 (0.15)*	-

Table 4-10 OEUR vessels below 10,000 DWT (GEUR in brackets)

			LIGW (million tons)		
Year	**Million DWT**	**No.**	**Tanker**	**Bulker**	**Dry cargo**
2001	0.84 (2.16)	65 (181)	0.03 (0.08)	0.04 (0.12)	0.11 (0.29)
2002	0.84 (2.16)	65 (181)	0.03 (0.08)	0.04 (0.12)	0.11 (0.29)
2003	0.95 (2.45)	52 (119)	0.03 (0.1)	0.05 (0.13)	0.13 (0.32)
2004	0.95 (2.45)	52 (119)	0.03 (0.1)	0.05 (0.13)	0.13 (0.32)
2005	0.95 (2.45)	52 (119)	0.03 (0.1)	0.05 (0.13)	0.13 (0.32)
2006	0.95 (2.45)	52 (119)	0.03 (0.1)	0.05 (0.13)	0.13 (0.32)
2007	0.73 (1.87)	46 (108)	0.03 (0.07)	0.04 (0.1)	0.1 (0.25)
2008	0.73 (1.87)	46 (108)	0.03 (0.07)	0.04 (0.1)	0.1 (0.25)
2009	0.73 (1.87)	46 (108)	0.03 (0.07)	0.04 (0.1)	0.1 (0.25)
2010	0.73 (1.87)	46 (108)	0.03 (0.07)	0.04 (0.1)	0.1 (0.25)
2011	0.73 (1.87)	46 (108)	0.03 (0.07)	0.04 (0.1)	0.1 (0.25)
2012	0.63 (1.62)	32 (73)	0.02 (0.06)	0.03 (0.09)	0.09 (0.22)
2013	0.63 (1.62)	32 (73)	0.02 (0.06)	0.03 (0.09)	0.09 (0.22)
2014	0.63 (1.62)	32 (73)	0.02 (0.06)	0.03 (0.09)	0.09 (0.22)
2015	0.63 (1.62)	32 (73)	0.02 (0.06)	0.03 (0.09)	0.09 (0.22)
Av.	*0.77 (1.98)*	*32 (73)*	*0.03 (0.08)*	*0.04 (0.1)*	*0.1 (0.27)*

4.4 Navy fleet

Naval vessels are excluded from international legislation, which is governing the building and operation of civilian vessels. The life span of naval vessels is typically higher than that of civilian vessels. Furthermore, substantial refits for the purpose of updating both performances as well as expanding remaining lifetime, is not unusual. These parameters have an impact on the decommissioning, disposal and scrapping patterns of naval vessels.

4.4.1 World navy fleet

The world navy fleet consists of some 20,000 warships. The vast majority of these are small vessels for patrol and supporting services. The world naval fleet distribution by type is presented in Table 4-11, and is further detailed in Appendix A.

Table 4-11 World Navy fleet in 1998 (ref.: /8/)

Region/organisation	Submarines *		Aircraft Carriers/Cruiser *	Destroyers/ Frigates *	Patrol vessels **	Misc. **
	Nuclear	Diesel				
Nato fleet	109	82	39	320		
Non-Nato-Europe fleet	72	52	18	51		
South and central Asia; East Asia and Oceania	6	154	2	277		
Middle East and North Africa; Sub-Saharan Africa; Latin America	0	48	3	105		
SUM	**187**	**336**	**62**	**753**	**6,218**	**11,836**

* *Data exclude vessels of less than 100 tons standard displacement. Figures are for June 1998.*
** *Data for vessels less than 100 tons standard displacement. Figures are from 1995.*

The largest navy fleet nations by numbers of warships of size above 100 displacement tons are presented in Table 4-12.

Table 4-12 Largest Navy fleets in 1998, sorted by vessel numbers (ref.: /8/)

Country	Submarines		Aircraft Carriers/Cruisers	Destroyers/ Frigates	Sum
	Nuclear	Diesel			
United States	84	0	31	97	212
Russia	72	26	18	26	142
China	6	57	0	53	116
Japan	0	16	0	57	73
France	10	2	2	39	53
United Kingdom	15	0	3	35	53
Korea, South	0	14	0	34	48
Other	0	221	8	412	641
Sum	187	336	62	753	1338

Note: Data exclude most paramilitary, security, and irregular forces. Naval data exclude vessels of less than 100 tons standard displacement. Figures are for June 1998.

Only 7% of the naval fleet (by numbers) is in the category of large warships (larger than 100 standard displacement tons). The number of submarines reported varies depending on source used. This deviation may be caused by insufficient updating in relation to scrapping, inconsistency in reference year and the adoption of different “grouping” parameters (size/ type).

Due to lack of data on small naval tonnage, this assessment focuses on the contribution from large warships (>100 tons standard displacement) and submarines.

4.4.1.1 Global distribution

The 1998 NATO fleet accounted for approximately half of all large warships in the world. The US navy fleet was the largest accounting for 1/6 of total, followed by Russia. Nuclear powered warships are operated by only a few naval fleets dominated by USA and Russia.

At the end of the 1980s, the Soviet navy had more nuclear submarines than all other nations put together. As a result of the START II disarmament treaty in combination with the high age of some of the early generations of Soviet submarines, this fleet has now been considerably reduced following the decommissioning of some 138 FSU submarines. This number is expected to increase over the years to come as more of the ageing classes of submarines are decommissioned. The status of the subsequent process of demolishing these vessels is not known in detail, but a high number of these vessels are laid up awaiting scrapping (ref.: /9/).

A number of 13 Russian submarines and 1 submarine from United Kingdom (UK) of an average displacement of 4,000 tons were reported scrapped in the period from 1990 to 1999 (ref.: /13/). In the same period, 16 large surface warships of an average displacement of 20,000 tons were reported scrapped (3 US, 2 UK and 11 Russian vessels).

A typical decommissioning age seems to be less than 30 years, and the age for scrapping less than 50 years. Assuming an average scrapping age of 50 year, and adopting a navy scrapping rate of half of the merchant rate, the volume of large warships to arrive for scrapping annually is estimated to 25 – 30 vessels.

4.4.2 US navy fleet

The historic US navy fleet decommissioning contribution is detailed in Table 4-13 (the number of US ships decommissioned after January 1st 1980 differentiated by type (ref.: /3/). The numbers of scrapped/ disposed vessel are also provided. The statistics indicates that a high fraction of the decommissioned submarines are scrapped, while surface vessels seems to be decommissioned to enter a fleet of contingency/ reserve or sold or used as targets. The data reveal a US scrapping rate of 1-5 vessels annually.

The US naval vessel register (ref.: /2/) refers to a “non-active vessels” category (containing approximately 3200 vessels, year 1924 and onwards). From this source, some 900 vessels are categorised as: *Disposed of, resold by Defence Reutilization and Marketing Service (DRMS) for scrapping* (not separated by vessel category).

Since 1993, a total of 23 scrapping contracts have been completed *based on DRMS* information (ref.: /14/). The contracts include 9 destroyers 2 minesweeper 1 submarine tender and 11 other. From this material, a scrapping rate of 1 large surface combat vessel each year has been established.

Based on the US contribution to the world naval fleet, a prediction of a scrapping rate of 9 large surface combat vessels each year is established. Following this approach, 12 submarines may be scrapped annually (based on Table 4-13). This scrapping rate (12 submarines of 523 submarines total) is comparable to the modified scrapping rate of the world merchant fleet (chapter 4.3).

Table 4-13 US ships decommissioned since 1 January 1980.

Type	Number	Scrapped/pending scrapping	For Disposal
Submarines	124	35/77	
Surface combat vessels	207	8	23
Amphibious	44		4
Coastal & Mine Craft	35		10
Auxiliaries	185		24
Other	28		7
Sum	623		68

Include: All USN combat vessels, support ships, auxiliaries, research ships, cargo vessels and test ships, including ships manned by the Military Sealift Command. All USCG and NOAA vessels over 65 ft long. Major vessels of the US Army, Air Force, other US Government agencies, and maritime academies. For the sake of completeness, nuclear submarines decommissioned before 1980 and major surface combatants in reserve in 1980 are included.

4.4.3 Europe

The European navy fleet (excluding Russia) is characterised by a higher average age compared to that of the merchant fleet.

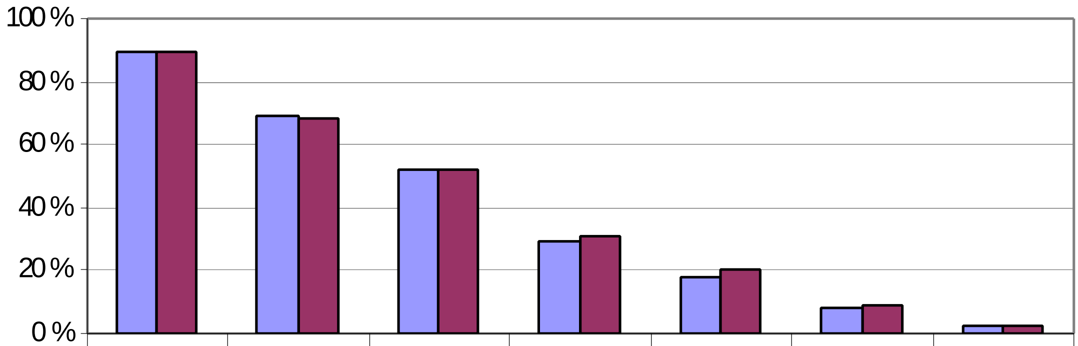
A total number of 194 frigates and destroyers of European nationality have been identified in the *World Navies Today* database (ref. /3/). The number of vessels and displacement weights have been summarised for the European countries (Belgium, Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Poland, Portugal, Romania, Spain, Turkey, Ukraine, United Kingdom and Yugoslavia) in order to display the variation in number of vessels and displacement weight as a function of age. The total displacement weight of this segment of the European naval fleet is approximately 707,000 tonnes.

Figure 4-6 presents the accumulated number of vessels and displacement weights as a percentage of the total (194 vessels and 707,000 tons). From the figure, it is seen that 2 % of the number of vessels in operation (corresponding to approximately 3% by displacement weight) are older than 35 years. The average displacement weight of the frigates and destroyers is approximately 3,600 tons.

Based on an absolute life-span of 50 years, the 2 % (4 vessels) of the fleet above 35 years will require scrapping within the next 15 year period.

Figure 4-6, an introduction of new tonnage at the rate of 16% in 5-year intervals is indicated. The expected scrapping rate for European frigates and destroyers may be assumed to be of the same order at approximately 6 vessels per year.

By adopting the same assumptions for the world's naval vessels (a total of 1338 vessels), an annual scrapping rate is estimated to 43 vessels. This figure is comparable to that found for the merchant fleet.



	> 5 year	>10 year	>15 year	>20 year	>25 year	>30 year	>35 year
No of vessels	89 %	69 %	52 %	29 %	18 %	8 %	2 %
Displacement	89 %	69 %	52 %	31 %	21 %	9 %	3 %

Figure 4-6 The number of vessels and total displacement as function of age (ref.: /3/)

4.4.4 Conclusion

Present scrapping rate of naval vessels is low, estimated to some 9 large surface vessels (above 100 standard displacement tons) and 12 submarines.

The future scrapping rate of large warships is estimated to be less than 2%. However disarmament treaty agreements and the high age of some of the earlier generations warships may cause an increase in scrapping rates for the period considered (2000-2015).

The contribution of scrapping candidates from the navy is negligible compared to that of the merchant fleet. This is mainly due to the size (relatively few vessels) and the high life-span expectation.

Naval vessels follow a different pattern when decommissioned from operational military service. This results in a relatively long lag-period before scrapping.

Assuming that global fleet distribution for small naval vessels (less than 100 displacement tons) equal that of the larger vessel, the NATO fleet consists of some 6000 – 8000 units, and further assuming a similar scrapping rate to that of the larger vessels, an annual scrapping volume is estimated to be 90 – 120 units.

4.5 Inland fleet

The world fleet of inland vessels consists typically of older and smaller units compared to that of the sea-going merchant fleet. The inland fleet composition mirrors the characteristics of the waterways they serve. In Europe, the inland waterway infrastructure consists of both rivers and connecting canal networks. The fleet includes non-propelled vessels and is subjected to geographical operational constraints.

4.5.1 World-wide

Table 4-14 presents the 1992 inland fleet of Europe, USA, Russia and countries of the former USSR. The figures are based on OECD statistics (ref.: /16/). The fleets of these nations consist of some 80,000 units representing a gross carrying capacity of 80,000 tonnes.

US and Russia dominate the scene accounting for approximately 40% and 30 %, respectively, in terms of numbers. The Netherlands is the largest operator of inland vessels in Europe at 8% of the world total.

By number, the inland fleet represents a similar size as that of the sea-going merchant world fleet. However, its cargo carrying capacity is on average less than 900 tons. Push-towed vessels account for a major part of the cargo carrying fleet, thus this varies somewhat according to country and region.

Table 4-14 may provide a general picture of the fleet composition and regional distribution. The fleet statistics presented here are 8 years old, and are limited to only some main inland transport regions. However, the size of the inland fleet has not developed in the latter part of the 1990s (Table 4-15/ Figure 4-7).

Table 4-14 Fleet composition 1992 (ref.: /16/). (Numbers in *italics* are estimated)

Country	Number of units		Gross carrying capacity (10^3 tonnes)			Average size of a river barge unit (tonnes)
	Total	Push-towed	Total	Push-towed	%	
Germany*	3749	1418	3328.7	1136.4	34.1	888
Austria	225	140	250.2	206.4	82.5	1112
Belgium	1845	292	1475	374.6	25.4	799
France	2878	989	1551.7	692.1	44.6	539
Hungary	249	145	251.2	*202.2*	*80.5*	1009
Luxembourg	28	0	28.6	0	0	1021
Netherlands	6534	1109	5818.1	1525	26.2	890
Poland	2102	1069	812.4	340.5	41.9	386
Switzerland	156	69	281.4	127.1	45.2	1804
Czech Republic	*543*	*469*	*321.6*	*245.4*	*76.3*	*592*
Slovakia	309	*309*	376.2	*376.2*	*100*	1217
Croatia	189	107	83.1	40.7	49	440
United Kingdom	830		205			247
Other European countries	274		370.6			1356
Ukraine	765	347	762	372.7	48.9	996
Baltic States	107	51	1.4	0.6	42.9	13
Russia	24559	2647				
Other countries of the former USSR	115	114	30.9	30.8	99.7	269
United States	34387	28615	42111	40190	95.4	1225
Sum	**79844**	**37890**	**58060****	**45861****		**822**

*former GDR & GFR
** Russia not included

4.5.2 EU- fleet

After the end of World War II, the growth of transport by inland waterways in Europe, co-ordinated by the various international authorities, resulted in an enlarged and integrated network brought up to a minimum standard for serving vessels of 1,350 tons (ref.: /17/). This formed the basis of the existing network of waterways. At present, only six EU member states have operational inland waterway networks: France, The Netherlands, Belgium, Luxembourg, Germany and Austria. Traffic density is closely linked to that of activity levels of the adjacent ports through which the main traffic is channelled (ref.: /16/).

In the European continent, a considerable growth was experienced in total tons carried by inland waterways from 385 million tons to 472 million tons in the years 1964-68. In 1938, Germany carried 90 million tons of freight on its inland waterways, and by the end of the 1960s, the Federal Republic of Germany alone was carrying over 230 million tons annually (East Germany was carrying an additional 12 million tons). Nor was this increase limited to the earlier years of the decade, as is shown by the volume of goods passing along the Rhine, which rose from 187 million tons in 1963 to 265 million tons in 1969. Most European countries could refer to the same substantial growth. The Soviet Union carried over its 233,000 miles of navigable waterways approximately 239.5 million tons in 1963. This had increased to 322.7 million tons in 1969 (ref.: /17/).

Despite the fact that the freight transport market in Europe almost doubled in volume over the period from 1970 to 1995, growth in the inland sector has remained stagnant. Until now, the waterways have primarily been used to cover transport requirements of traditional manufacturing sectors, those that have been hard hit by industrial restructuring. The waterway network can be readily incorporated into logistics chains in which regular supply streams and low transport costs are more important than speed. The transportation of hazardous materials and container transport are also offering promising markets (ref.: /17/).

The restructuring and upgrading of the European waterway network was gradually integrated into to the work-scope of the EU. Arising out of this came the scrapping scheme (Directive No. 1101/89) initiating a systematic restructuring of the inland waterway fleet. The restructuring is now almost complete on the Rhine and the Rhone and in the Netherlands, where the waterway sector is experiencing renewed growth (ref.: /17/).

The western European fleet is being renewed by the introduction of self-propelled push-tow barges better adapted to the needs of containerised transport. The East European fleets need to be modernised. Barges are still most often towed and the technical standards, particularly those associated with safety, are still inadequate. In some countries, such as Poland, the size of the vessels is relatively small (ref.: /17/).

Table 4-15 presents the EU fleet separated by country and vessel category (ref.: /4/). The 1997 fleet consisted of 15,471 self-propelled cargo-carrying vessels and 4,016 dumb and push barges (vessels not based on own propulsion). The age distribution of self-propelled inland waterway vessels is shown in Table 4-16. Assuming that the age distribution in this table is representative of the whole fleet, this clearly indicates a dramatic reduction in supply of new tonnage in the last decade. Based on this and the development in volume of vessels operating the last ten years, a scrapping rate of approximately 200-300 vessels annually has been estimated (from Table 4-15). This rough estimation is only based on the net reduction in tonnage, but replacement of old tonnage would also involve some scrapping.

From Table 4-17, it can be seen that the average size of the vessels is approximately 650 DWT. It follows that the expected tonnage scrapped annually will be no more than 0.2 million DWT. By comparing inland merchant fleet scrapping volume to that of the world merchant fleet, its minor influence as a source for recycling industries becomes evident.

Looking at a scenario where it is assumed that the tendency seen in the last decade continues to develop and the supply of new tonnage cease, in the period from year 2000 to 2015, the fleet may be reduced to some 12,000 vessels. However, some supply of new tonnage may counteract this trend and balance the numbers. The considerable backlog of very old vessels (approximately 70% of the number of vessels in the fleet was built before 1969) will require an increasing degree of replacement within the period (2000-2015). It should be noted that new vessels are likely to be larger than the older, and hence balancing the numbers should reflect this.

Figure 4-7 shows that the decrease in number of vessels has levelled out in the period from 1993 – 1996. Note that there may be changes in the tonnage distribution not envisaged by the illustration presented.

Looking at the average inland vessel's characteristics and size, these vessels will most likely be scrapped in Europe.

Table 4-15 Inland Waterway fleet statistics, EU Member States (ref.: /4/).

Goods Transport

Inland Waterways **3.11**

Inland Waterways Transport Equipment

	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK	EU15
Self-propelled goods vessels, tugs and pushers (units)																
1970	5 092		6 038			5 790		3 124	17	9 885	57		90		390	**30 483**
1980	3 107		4 464			4 254		2 347	18	6 966	64		113		381	**21 714**
1990	1 871		3 230			2 514		2 755	25	6 136	61		136		396	**17 124**
1993	1 665		3 135			1 829		2 847	36	5 755	51		157		403	**15 878**
1994	1 650		3 018			1 803		2 853	44	5 678	40		160		403	**15 649**
1996	1 566		3 538			1 640		*2 850*	*44*	5 345	47		164		277	**15 471**
1997			2 152			1 479					42		164		277	
Dumb and pushed barges (units)																
1970	455		2 200			1 591		393		1 523	225		70		1 610	**8 067**
1980	190		1 732			1 211		217		925	150		57		1 228	**5 710**
1990	164		1 566			768		372		937	171		23		411	**4 412**
1993	169		1 291			740		381		890	147		23		427	**4 068**
1994	*171*		1 313			775		*390*		900	130		23		427	**4 129**
1996	169		1 277			760		*350*		922	157		20		361	**4 016**
1997			1 273			694					141		23		361	

Source : Eurostat / ECMT / UN-ECE , national statistics

Note : figure for Italy includes large number (1993 : 1939) of small vessels (<10t) used in Venezia

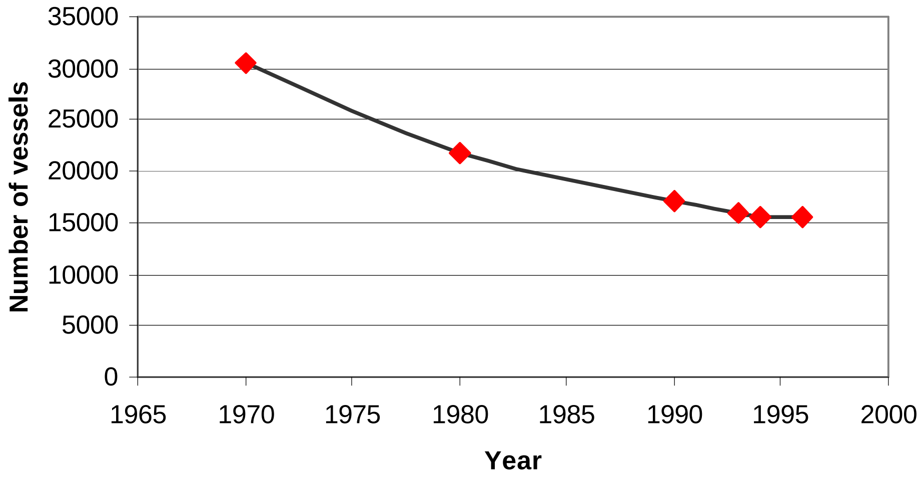


Figure 4-7 Development of the inland merchant fleet.

Table 4-16 Age distribution self-propelled goods vessels in 1996, EU inland water crafts* (ref.: /5/)

Age distribution	%
Up to 1949	25.0
1950-1969	43.6
1970-1979	11.8
1980-1989	16.7
1990 and over	2.8
	100

* based on the data from 4677 vessels

Table 4-17 Size distribution self-propelled goods vessels in 1996, EU inland water crafts* (ref.: /5/)

Tonnage distribution	%
Up to 249 tonnes	6.9
250-399 tonnes	27.6
400-649 tonnes	20.5
650-999 tonnes	14.3
1000-1499 tonnes	17.6
1500-2999 tonnes	12.7
3000 tonnes and over	0.4
	100

* based on the data from 4692 vessels

4.5.2.1 The future of the European waterway fleet

The OECD has summarised the perspectives of the inland waterway network of Europe as follows (ref.: /16/):

- On the whole, the future of the waterways lies more in new markets than in the spin-offs from possible changes in the current modal split.
- Many countries have experienced significant growth in the transport by inland waterway of products not normally carried by that mode.
- Waterway transport can be integrated into logistical chains in which regular flows of supplies and low costs are more important than speed.
- The Rhine and the Danube are the two major river corridors in Europe. The Rhine will continue to be a major corridor in the future, due to qualitative progress in the handling of traffic flows.
- Living standards in eastern European countries will rise and the integration of these countries into the world economy should accelerate, thus stimulating growth in traffic flows.
- The future for waterway transport is all the more secure in that it will be difficult for road transport to absorb the very strong growth forecast in goods traffic; the road transport market, however, is relatively distinct from the waterway market.

4.5.3 Conclusion

The scrapping contribution from the Inland merchant fleet seems to be negligible as a source for steel recycling industries compared to that of the merchant fleet.

However, due to the high number of units represented by the fleet and its age composition, it is likely that a considerable number of these vessels will require scrapping in the period considered. The individual scrapping candidate will not resemble that of a merchant vessel with respect to output (recyclable share). This is an argument for undertaking scrapping of small tonnage within Europe.

4.6 Conclusion – all vessel categories

All "marine vehicles" have a limited operational (design) life span and will consequently require some form of end-of-life disposal at some predictable point in time.

This chapter has assessed the volume and composition of scrapping candidates over a 15 year perspective (2000-2015) and made predictions based on statistics and common practice for the respective category.

The merchant fleet represented by the cargo-carrying segment represents by far the largest contributing category to the scrapping industries by tonnage. The decommissioning patterns associated with offshore structures and naval vessels are influenced by constraints of political nature whilst the decommissioning of inland waterway vessels is governed by practical and operational constraints.

Offshore;

The closedown of 90 fields by the year 2000 with a lag period of 2-20 years before scrapping following decommissioning is likely to represent a backlog representing some 4 units annually (29,200 tons/ year steel). Over a 15-year period this will accumulate to 438,000 tons of steel structures. An additional demand may be represented by the 160 fields expected decommissioned in the interval from year 2000-2015. If these are assumed arriving at a constant rate and scrapped without delay, some additional 80,000 tons of steel (11 units) annually will arrive from offshore structures from year 2010. The final fate of offshore structures is not necessarily that of being scrapped. The figures presented in this chapter do not account for alternative usage.

Merchant fleet;

The average scrapping age of cargo vessels is approximately 26 year, and the main scrapping contributors in terms of tonnage are bulkers and tankers. The main scrapping countries are Bangladesh, India and Pakistan. Double hull requirements may cause longer lifetimes of cargo vessels (tankers). However, incidents may influence regional legislations and hence counteract this trend. The annual expected scrapping rate is about 500 vessels/year and 25 million DWT depending on fleet development, and age and size distribution. 66 % of the number of European ships scrapped in 1999 was scrapped in non-OECD countries and this represents 93 % in terms of dead weight.

Naval fleet;

Present scrapping rate of naval vessels is low, estimated to some 9 large surface vessels (above 100 standard displacement tons) and 12 submarines. The annual scrapping rate of large warships has been estimated to be less than 2%. However, disarmament treaty and the high age of some of the earlier generations warships may generate peaks within the period considered. The scrapping contribution from navy fleets seems to be negligible compared to that of the merchant fleet due to lower number of large vessels and a higher scrapping age. A considerable share of decommissioned navy vessels is kept as a contingency prior to disposal. A scrapping rate of European navy vessels has been found at 6 units annually. A considerable part of the world's naval fleet consists of smaller vessels. Some 93% by numbers are of less than 100 tons standard displacement and consequently not represented in the figures above. These smaller vessels have typically a lower average age when decommissioned. Assuming that the distribution pattern for these smaller vessels is identical to that of destroyers and frigates, the European share of naval vessels of less than 100 standard displacement tons are approximately 36% (some 6,600 units). Furthermore, assuming that the average scrapping rate for the smaller vessels equals that of the larger naval fleet, a volume of 132 European smaller naval vessels requires disposal.

Inland waterway fleet;

The scrapping contribution from the inland waterway fleet is negligible compared to that of the merchant fleet in terms of tonnage. Inland waterway vessels are diverse from the merchant fleet not only by size but also by age as these vessels are kept in operation for a considerably longer time than the merchant fleet. However, due to the high number of units represented by this fleet and its age composition, it is likely that a considerable number of these vessels will require scrapping in the period considered. The individual scrapping candidate will not resemble that of a merchant vessel with respect to output (recyclable share). This is an argument for undertaking scrapping of small tonnage within Europe.

Assuming that nearby 70% of the European inland waterway fleet was built prior to 1969 (ref. Table 4-16) and further assuming a 2% scrapping rate, an annual number of 216 vessels to be disposed of can be expected for the period. Dumb and pushed barges would come to 56 vessels annually in addition.

5 CURRENT PRACTICE

5.1 Industry Characteristics

There has been little or no commercial ship scrapping activity within Western Europe over the last 10 years. World-wide scrapping activity has centred on India, Bangladesh, Pakistan and China. Additionally there has been some recorded scrapping in Spain and Turkey.

The capacity in the Indian sub-continent and SE Asia is conveniently located close to the majority of trade routes. The Indian sub-continent covers the major trade routes of the Far East to the Middle East and Europe whilst China covers the trade routes within Asia and across the Pacific. These locations tend to minimise transport distances for vessels as they can often be stemmed with a cargo close to the final point of disposal. Perhaps the only major trade routes not adequately served are those across the Atlantic and through to the Mediterranean and West African coastlines.

Predominantly, scrapping activity has been most evident in the Indian sub-continent, where the process involves the beaching of vessels, and subsequent manual break-up and dismantling. It is this type of activity that causes major concerns on environmental, health and safety and social grounds. The major environmental concern is lack of containment to prevent toxins from entering the water, the land, the air or humans.

Manual, low paid workers are allowed to dismantle the ships without the provision of safety equipment, and scant attention is paid to health and safety issues or training. Injuries and deaths are common place. Similarly, environmental concerns are low on the agenda of the workforce, with little attention paid to the pollution occurring to land, air and sea as a result of their activities. Against Western European standards, these methods of scrapping fail to comply on almost all aspects of health, safety and environmental concern.

The extent and nature of non-compliance associated with ship scrapping activities in these countries is identified in the following section which is based upon an on-site case study undertaken at the scrapping sites at Fauzdarhat, Chittagong in Bangladesh. It can be seen that the gap to be bridged to achieve compliance is potentially huge, and would require capital investment in facilities, process control and radically different working practices and conditions. Furthermore, the local legal and cultural framework would need to be in place to ensure that any new environmental and health and safety measures that are introduced would be adhered to.

However, against local standards the situation does not seem so detrimental, as priorities are different and few alternative lifestyle opportunities are afforded. There is no doubt that the impact of these industries on the local community and economy is considerable and this must be considered in possible solutions. The situation in the other main scrapping countries is not necessarily identical, but to some extent similar issues exist.

There is effectively no existing scrapping activity for merchant vessels within Europe, and hence non-compliance is not really relevant. Elsewhere in the world the compliance gaps to be addressed are substantial and the climate in which to do this not conducive.

As a result of abundant low cost labour, and the level of non-compliance with Western European standards, the existing yards have the advantage of low operating costs. The less well developed countries such as India, also provide a ready market for many of the components that arise out of the ship scrapping process, such as pumps and generators. These components would not necessarily comply with regulations that would permit their reuse in Europe. The marketplace for these components also makes the transport of recovered materials very cost effective.

It would be difficult to ignore the social implications of removing large volumes of scrapping from these existing operations, as they generate employment and revenue for the local economy. The sustainability of any proposed changes to these operations would have to take into account the effect of balancing the environmental, social and economic issues.

In summary, the existing locations offer two critical factors:

- An abundance of low cost labour willing to do this dirty and dangerous work.
- A ready market to re-use many of the dated items on the vessels, such as pumps, generators, compressors, etc.

Relocating the industry would likely result in:

- Increased labour costs, which would have to be offset by improved methods of working to enable greater mechanisation.
- Increased transport costs to move many of the re-useable items to the markets, or a net reduction in the re-use element of the disposal process.
- Increased controls and legislation requiring considerable investment in facilities to bring the process up to meet international standards.

5.2 Non-compliance in Current Practice

Current ship scrapping is based around the principle of maximum separation and mirror a reverse "building" process being similar in that it is labour intensive but does not however make use technology commonly used in ship building. At present these operations are undertaken virtually without any mechanised aids on beaches by unskilled labour.

Scrapping sites are non-facilitated beaches including adjacent areas with some degree of infrastructure available. There may be some variations in adopted procedures by location, but the general contexts are very similar. Consequently, the findings from the case study of the sites at Fauzdarhat, Chittagong, Bangladesh are assumed to be generically valid and hence relevant for how the majority of tonnage (90% by DWT) is scrapped. Ref.: /20/ provides details from this study.

5.2.1 Adopted practices

The choice of location for the establishment of scrapping sites rests upon some priority requirements;

- A long uniform intertidal zone/ sufficient tidal difference (allowing vessels of a range of sizes to be "dry-beached)
- Minimum exposure (coastal protection) and stable weather conditions.
- Availability of low cost labour.
- A certain level of infrastructure.

The scrapping process follows a sequential pattern that can be described in a series of four steps:

1) **Offshore:** Prior to beaching, tanks are discharged and valuables (mostly electronic equipment) are removed.
2) **Intertidal zone:** The vessel is beached by own power and dismantling is initiated (in a certain sequence).
3) **On the beach:** Sorting of components and further cutting into manageable pieces for further transport.
4) **On shore/final destination:** Re-use 'as is' of different components/materials (second-hand market) and re-manufacturing/recycling into new products/components.

These steps are elaborated on in Figure 5-1 and Figure 5-2.

5.2.2 Safety, Health and the Environment

An inventory (Inventory of best practices, see Figure 5-2) complying guidelines, procedures, standards and requirements referring to actual operations covering both the ship breaking process as well as that of re-use or recycling should be identified. Such inventory will include a mutual section for practices related to the identification and handling of materials, items and hazards covering all SHE-aspects identifying minimum requirements for the ship breaking facility and the associated recycling processes including operational procedures. It should also address incidents and requirements associated with such (contingency preparedness). At a developed stage, this inventory will in effect serve as an Environmental and Safety Manual (ESM) for the ship scrapping facility.

Such requirements should cover the facilities themselves as well as operational procedures. Listed below are some examples:

1.	Facility Layout	Work task separation (requirements to work surfaces and drainage); Material separation (waste separation facilities).
2.	Operational procedures	Use of machinery and tools (procedures when using winches/ cranes, touch cutters, etc. (clearance zone, protective gear); Handling of hazardous substances (procedures for personal protection, storage and transport)

Adopted standards must reflect and comply with national regulations or regulations where applicable.

Stage	**Purpose**	**Minimum requiren**		
		Safety	**Health**	
Offshore - Quayside	Removal of; residual cargo/ wastes/ ballast/ oils/ salables, etc	Protective wear/ equipment	Protection from exposure, monitoring	
Intertidal zone	Access/ *gross* demolition	Protective wear/ equipment	Protection from exposure, monitoring	
Onshore – Scrapping site	*Fine* demolition and sorting	Protective wear/ equipment	Protection from exposure, monitoring	
Onshore – Final destination	Reuse/ resale/ recycling/ reprocessing	Protective wear/ equipment	Protection from exposure, monitoring	

Figure 5-1 Compliance to basic requirements

ESM		
Safety/ Health	**Environment**	
Occupational Safety and Health Plan	Environmental Management Plan	Conting
Inventory of best practices		

Figure 5-2 Schematic example on SHE-procedures; *The overlaying requirement to safeguard all SHE-aspects tl procedures. Such procedures will incorporate requirements to third parties (documentation and preparations), as w methods adopted, workers skills, emergency measures, etc., and may be organised in an Environmental Safety Manu facility.*

The ESM approach is a managerial tool for the operation containing references to all relevant norms, standards, regulations etc. and provide for implementation, maintenance and continuos improvements. Based on an identified safety and environmental performance policy to be adopted by the scrapping facility, the manual rests on identified safety and environmental performance criteria. Through defined procedures, conformity (or non-conformity) with the identified policy can be monitored and verified.

5.2.3 Compliance mismatch

Most nations involved in ship scrapping will be able to make reference to some national guidelines and/ or recommendations covering both safety and environmental issues. However, it is evident that these are not implemented or adhered to.

From Figure 5-1 and Figure 5-2, it is evident that even though the work follows a certain pattern of logic, it fails to comply with the most general expectations in terms of precautions with the potential of causing serious safety violations and causing harm to workers health and the environment. The absence of overlaying plans and policies, lacking in facilities, lacking procedures, lacking skills requirement and appreciation of training needs represent sufficient inadequacies to draw the conclusion of general non-compliance. The findings from the case study undertaken by DNV at Fauzdarhat, Chittagong, Bangladesh (ref.:/20/) is a documentation of this.

5.2.4 New Initiatives

The industry is to some extent recognising its failure to comply and there are some initiatives aiming for changes. The most promising current activities associated to the development of ship scrapping as an industry, may be illustrated by emerging initiatives:

- An Australian ship scrapping project; this is being led by Australian Steel and a number of big backers (Deutsche Bank, AMEC, ABB, etc). However, this has been 3 years in the planning and a number of site selections have been rejected, other sites have been selected and the project team would consider a suitable opportunity in Europe.
- Offshore facilities, there are at least 3 offshore facilities that are active in offshore rigs/platform de-commissioning in Europe. Two located in the UK and one in Norway. These are interesting because they have a different cost/income structure to the traditional ship scrap yards.
- Development/opening of a new ship demolition yard at Pipanav in India, which is being built with Japanese help – most notably loans for 85% of the project cost. This is a dock based facility comprising 2 very large docks (700m x 60m) which is being equipped to be more environmentally friendly and less hazardous than the nearby beaching facilities at Alang. The design capacity of this facility is 8 VLCCs per year.
- Finally there is has been some news items regarding P&O investing in the upgrading of a Chinese facility to enable it to meet international standards.

It should also be noted that recent initiatives at existing sites on SHE issues has been announced including the establishing waste reception facilities and medical treatment facilities. However, whether the extent of these initiatives will be sufficient to achieve compliance is unsure.

The offshore facilities and the US attempts have deviated from the established traditional financial scenario in which the owner is paid money by the scrap yard to purchase the vessel for scrap with the price usually determined by the steel weight. In the US and the offshore sectors a number of contracts have been executed where either there has been zero payment to the owner or the owner has had to pay to have the marine vehicle disposed of.

5.3 Adopting Current Practice in Europe

Ship scrapping of the dominant merchant vessel category at the current time is almost exclusively undertaken in countries such as India, Bangladesh, Pakistan, etc. where the practices are non-compliant in respect of SHE considerations.

The basic concept of the scrapping process in these countries is to dismantle the vessel into component parts and manageable sized units of structure. In the general recycling environment this task is referred to as separation, and is usually highly labour intensive. The benefit of undertaking a high level of separation is however that the resultant material output streams are more easily reusable or recyclable because the mix of materials is reduced. For example, separation of pipework into straight tube lengths, welded bends, flanges and valves allows much greater flexibility for re-use than a prefabricated section of pipework. Similarly, separation of steel structure from insulation, cement compositions, cable trays or windows provides a purer source of steel for recycling. This results in potentially higher income streams from resale.

A large part of the economics of recycling therefore is a trade off between the cost of separation and the increased resale opportunities and value for the resultant material output. Where separation is largely a labour intensive process rather than a mechanised or chemical process, the balance between separation cost and material value is very different according to the labour availability and cost in the country in which it occurs. In many recycling industries, the balance is such that recycling becomes a net cost item rather than a revenue generating activity. This situation is further exacerbated by the volatility of waste material prices in the commodity markets. In some instances after initial separation/ processing and compacting, materials are exported to lower labour cost countries for ‘hand picking’ or further separation.

The value of an item for re-use is generally greater than that for recycling and in the environmental hierarchy this may also be a more desirable option. Therefore the ready availability of local markets for the re-use of components within a particular country is also a significant factor in terms of the overall economics of recycling in general and ship scrapping in particular. Within Western European and EU countries there are both cultural or mental and legislative barriers to the principle of re-use. Product labelling, safety regulations, material traceability requirements etc. present practical hurdles to the re-use of “second” hand components. Also client expectations are generally towards buying new rather than second-hand. This means that the markets that exist in countries like Bangladesh, India or China for the resale of components, such as valves, pumps, generators and washbasins to name just a few examples, do not exist to any meaningful extent within these Western European countries. The exception may be that of spares and reconditioned components for ships in operation. However, this is a highly specialised area and represents a very limited market.

It can be seen therefore that adoption of the current ship practice of maximum separation would operate at a disadvantage in several respects, including:

- Additional costs of adopting SHE compliant practices
- Cost of separation

- Non-availability of local re-use markets and the revenue streams associated with these

There are other characteristics of ships that need to be taken into consideration when evaluating the overall economics of scrapping in comparison to recycling technology in other sectors. Firstly the physical scale of the item to be recycled and some of its component parts presents some problems. The ship's structure itself, which is predominantly steel is too large and heavy to be easily handled or transported. Additionally, this structure itself is designed to have considerable strength and rigidity. Crushing or compacting technology that is used in other industries cannot therefore be readily applied to reduce the physical size of the unit for transport – so unlike car bodies it is not practicable to crush the ship's hull. Even after cutting into smaller sections, the ship's structure is likely to be very space consuming. Continuing with the car comparison, specialist units exist for recycling car engines, however the physical size of ship's engines (or the sub-units of these) and most auxiliary machinery is both heavier and larger.

All in all it is hard to find a comparison of items of similar size, structural strength and weight, and complexity to ships within existing recycling practice. Even large buildings like hotels or power stations are more easily reduced to manageable size by demolition (impact or explosion).

The scale problem is also dominant at the bottom of the recycling chain with disposal. Traditionally disposal by landfill was considered the option for items which are not harmful in themselves, but for which the cost of recycling is high. Landfill undesirability in current recycling terms is reflected both in the legislation requiring re-use or recycling and also in the escalating costs of landfill. In such instances the materials are compacted to reduce the volume. It is evident however that the physical space required of to dispose of some 100 - 250 ships per year even if the question of compaction could be addressed is enormous. Perhaps, the marine equivalent of landfill has been the practice of sinking vessels at sea, however such activity has to be licensed and increasing environmental awareness and legislation over the protection of the marine environment would suggest that this practice is not an option for the future.

It would seem therefore that adoption of the traditional scrapping practices within European countries is not a practical option given the costs of separation and the absence of secondary markets for components. The approach that has been adopted for the basis of this report is therefore the adoption of limited separation into a number of primary waste stream categories for recycling rather than re-use.

6 MATERIAL COMPOSITION AND RETURN TO MARKET

6.1 Background

The overriding culture of recent times is that as a society, it is no longer acceptable to dispose of materials in a fashion which may cause harm to our environment, or to the future generations. Furthermore, the justification of applying the principles of sustainability to resource management is achieving broad acceptance and recognition in both industrial segments and also in society in general. This is mirrored by the fast growing acceptance of re-use and recycling of materials wherever possible.

6.1.1 Changes in resource management and policies

To this end there is a growing amount of legislation coming mainly from the EU, which is forcing our populations to view the way in which waste is handled. It is no longer acceptable to dispose of waste to landfill or incineration without giving some thought to having the material recycled.

The packaging waste directive, which obligates us to recycle a percentage of all packaging waste, and the forthcoming Waste Electrical and Electronic Equipment Directive, as well as the End of Life Vehicle Directive, are all forcing us to change the way that we view the disposal of goods when they reach the end of their useful life.

The forthcoming EU Landfill directive will obligate us to reduce the amount of waste we send to landfill and will no longer allow us to landfill biodegradable waste (this includes paper and pulp products), and will also limit landfill for certain types of hazardous waste. This will lead to rising costs for waste disposal, and a review of materials, which were once deemed uneconomic to recycle, as paying for recycling may well prove less costly than waste disposal.

Landfill charges used as incentives to improve waste and recycling management in Europe, are still reasonably low. In the UK the cost of disposing of controlled waste is $26 per tonne rising to $45 per tonne for hazardous waste. An increase in tax of $1.50 per tonne every year for the next three years has already been approved, and as regulations on landfill operators become more onerous, landfill charges in general are expected to rise at a faster rate than this.

Incineration of certain materials is also an option. Mainstream incinerators require huge capital investment and long term contracts for both waste and delivery of the energy its provides. The establishment of such plants require permissions which often have proven difficult to obtain due to objections from surrounding communities.

The change in attitudes towards, and methods of waste disposal, mean that goods, which may once have had a residual value when they reach the end of their working life, such as motor vehicles, will now cost for disposal.

6.1.2 Changing provisions for ship scrapping

For a ship, the governing parameters differ according to category and size as visualised in Table 6-1. Policies and decisive factors on these issues are elaborated upon in chapter 3.

The methods applied in the merchant fleet have developed from the prime objective of profit-making, and thus, this has been the main driver on shaping the concept of current scrapping procedures. Media exposure and growing awareness materialising in new policies are however introducing new views and may slowly impact the established scrapping principles. For the remainder categories, other parameters have had an impact on the process of decommissioning and scrapping.

In general, material composition determines the recycling potential and further the challenges associated to the required extraction processes for complex products. Re-use/ recycling may not be restricted to the re-use of single components or the recycling of material (steel) arriving from structure, but may imply partial demolition and re-use of major elements of the original structure. Examples might be the re-use of offshore modules at new locations or partial demolition of a vessel and utilisation of structure as artificial reefs or as diving objects (see section 6.3 for further examples). The use of partial demolished vessels may be regulated by national or internationals regulations, i.e. the London Convention (convention on the prevention of marine pollution by dumping of wastes and other matter).

Table 6-1 Governing parameters for scrapping in four categories

Vessel category	Parameters governing scrapping practices	Comments
Offshore structures	Policies, media exposure, regulations	Oil majors environmental policies.
Merchant world fleet	Economics, size	Profit-making, third world employment opportunities, international conventions.
Navy fleet	Politics/ policies	Comprehensive decommissioning procedures and (inter-) national politics.
Inland fleet	Economics, size, geography	Size limits geographical scrapping opportunities.

6.1.3 Minimising waste – maximising recycling

The waste streams for all four vessel categories are dominated by the contribution of steel. Even though the remaining materials will differ both with respect to value in the recycling chain and on requirements in association to waste handling for different vessel categories, it is assumed that the merchant fleet will reflect the broadest of scenarios. This and the comprehensive dominance of the merchant fleet in the scrapping context, is reflected in the following.

In terms of ship scrapping, there is the potential to create massive annual volumes of materials for re-use, recycling or disposal. A significant proportion of this waste stream is steel for which recycling options exist. However, there is also a considerable volume of other materials which must be catered for. The following sections assess the composition of materials under main primary waste streams and look at requirements and options available for re-use, recycling or disposal. This forms the basis of the economic analysis presented in chapter 9.

6.2 Material composition and waste streams

Beside type and size, the required functions of a specific vessel will be determining for the configuration of onboard materials and systems and consequently the waste stream configuration which will influence requirements for the scrapping facilities.

6.2.1 Material composition complexity

To enable assessments of waste streams and quantities from the dismantling process, the vessel has been segmented into spaces:

- **A** Cargo spaces
- **B** Machinery spaces
- **C** Accommodation spaces

The composition of these spaces in terms of complexity/ density of components and material composition varies significantly. The ABC approach allows simple breakdown as function of material composition complexity and allows waste stream quantification to be undertaken.

The cargo space areas represent large low density volumes of the vessels bounded by ships structure and containing mostly only simple items such as pipework and outfit steel including ladders and hatch covers. There may also be limited amounts of cabling, instrumentation and selected machinery items.

The machinery space areas represent steel structure surrounding high-density areas comprising predominantly heavy machinery items including the main engines, generators, auxiliary machinery and pipework. There will also be significant electrical cabling, electronic equipment, instrumentation, insulation and outfit steel in such areas. Overall, a far greater diversity of original materials will be present than in cargo, tank or void spaces.

The accommodation space areas however whilst also high-density areas surrounded by (generally lighter scantling) steel structure have a marked difference in the composition comprising hotel outfit (furniture, furnishings, sanitary) within joinery sub-divided areas, together with electrical and electronic equipment and controls in the navigation and domestic areas. These areas require high levels and complex utility provision involving pipework, electrical cabling, ventilation trunking and comfort insulation.

Different ship types will have different mixes of these three area types and further, the composition within the areas will differ accordingly.

For simplicity, the total steelweight of the vessel has been included in the A category together with any outfit in those areas. The total lightweight of the vessel can be considered to comprise:

LIGHTSHIP = **A** (STEELWORK/ OUTFIT)+ **B** (MACHINERY/ OUTFIT) + **C** (JOINERY/ OUTFIT)

Different ratios by weight for different vessel types are presented in Table 6-2. This can be used as a basis for calculating an illustrative 'average' composition reflecting the mix of ship types in the fleet.

An average "ship" can be identified based upon the composition of the world fleet into these different ship types and a weighted average calculation for the relative weight breakdown. The above calculation has defined this average vessel composition by weight as:

Lightship = (75% A) + (12.5% B outfit) + (12.5% C outfit)

In the following sections the major component waste streams for ships have been identified and the relative mix of these for each of the above 3 categories estimated.

Table 6-2 Different ABC ratios by weight for different vessel types

Ship Type	Lightship Tonnes	A %	B + C %
Cargo ship 400,000 dwt	53,500	85%	15%
Cargo ship 200,000 dwt	29,400	84%	16%
Cargo ship 100,000 dwt	18,300	80%	20%
Cargo ship 70,000 dwt	16,700	77%	23%
Cargo ship 20,000 dwt	8,300	69%	31%
Cruise vessel 2,000 pax	23,000	44%	56%
Pass/RoRo ferry	985	59%	41%
Fishing vessel	1,416	30%	70%
Offshore supply	765	51%	49%
Dredger	2,379	63%	37%
'Average fleet vessel'	**100%**	**75%**	**25%**

Ship dismantling requires the redundant product to be broken down into component material waste streams for recycling. Such waste streams can be considered as falling into three categories:

- Revenue generating
- Requiring disposal or safe processing for which there is a cost
- Neutral cost disposal

The purity of the waste streams will generally affect its potential value where revenue generation is possible. However, separation is required to achieve such purity, which involves processing cost arising out of a labour intensive process. An economic balance exists therefore between value of the waste streams and cost of separation.

6.2.2 Waste streams

For each stream it is necessary to establish the disposal route from the dismantling yard. In environmental terms the hierarchy is:

- Re-use
- Recycle
- Disposal

Table 6-3 identifies the primary waste streams that have been used in this study for the purpose of quantifying the waste output and net revenue/ cost of this. The content of the "waste stream list" includes a variety of different substances commonly found in all four vessel categories, but may also contain substances that are relevant only for specific vessel categories or particular ship types.

Table 6-3 Waste streams from ship scrapping

Material stream	Where is it found on board a vessel?
Ferrous scrap metal	Outfit and structural steel, hatch covers, pipes and pipe fittings, castings (stern frame), anchor and chains, propeller shaft, rudders, wires, sheet metals, tanks (non-integrated)
Nonferrous scrap metal	*Copper*: cables, pipes, motor windings, fittings, domestic pipework, etc. *Aluminium*: anodes, wheelhouse *Zinc*: anodes *Special bronze*: propellers, fittings
Machinery	Main engine, auxiliary engines, pumps, generators, boilers, separators, steering gear, deck machinery, cranes, etc.
Electrical and electronic equipment	Switchboards, consoles, control panels, navigational aids, domestic electrical items, instruments, sensors, etc.
Minerals	Asbestos and mineral wool for insulation, ceramics (domestic sanitary equipment), concrete, tiles, glass, windows etc.
Plastics	Plastic pipework, fittings, furniture, light fittings, life boats, rafts, etc.
Liquids, chemicals and gases	Fuels, fuel oils, lubrication oils, hydraulic fluids, polluted waters, refrigerants, cargo residues, sludges, chemicals, etc.
Joinery	Timber, joinery bulkhead and deckhead panels, accommodation doors and frames, furniture and furnishings, composite timber products, etc.
Miscellaneous wastes	Domestic wastes, radiation sources (equipment, scale), mercury (i.e. in level switches, light fittings, thermometers), batteries, marine growth (fouling/ ballast water and sediments)

6.2.3 Material stream – quantities and qualities

For the **offshore category**, volume data on material and waste streams from a number of installations in the North Sea has been compiled in order to establish generic waste stream estimates for a “unit installation”. This represent a coarse simplification since all installations are different, hence the data produced must be used keeping this in mind (ref./25/).

In order to establish some generic norm in relation to volumes from the **merchant fleet category**, lightship data and empirical formulas have been adopted enabling the quantification of main contributing categories (steelwork, machinery, accommodation, etc). By applying detailed data arrived from a case vessel (ref.: /19/), a further breakdown in order to estimate the identified waste streams has been made.

The diversity of the **naval and inland waterway fleets** makes waste stream quantification a difficult task. Further, looking at the volumes they generate compared to that of the sea-going merchant navy, their contribution becomes negligible. Material quantities from these categories can be estimated by using the data arriving from the merchant fleet and the volumes (tonnage) arriving from naval and inland waterways.

Basis and data used in the quantitative assessments are presented in Appendix B.

The fleet of merchant vessels is by far the largest provider of waste streams and hence represents the obvious opportunity with respect to the development of cost effective solutions. The study has therefore concentrated efforts on assessing the potentials of this category.

6.2.3.1 Ferrous scrap metal – Non-ferrous scrap metal

Steel scrap represents the largest recyclable fraction from the merchant fleet and is commonly classed as ferrous scrap, of which the largest proportion is so-called “carbon steel”. Non-ferrous scrap, often of particular interest due to it’s relatively higher value, comprises metal scrap of alloys.

The scrapping facility may recycle scrap metal by selling it to a re-smelting/ re-rolling company or a scrap metal broker.

At the present time, there is an international standard maximum size for steel scrap of approximately 1.5 x 0.5 x 0.5 metres. The projected volume from a ship dismantling facility within Europe would provide a major single source of scrap steels, the like of which we believe does not currently exist. It is not clear whether a dedicated stream of waste of such magnitude would change this limitation, however current furnace technology does impose geometric constraints.

The amount of steel will vary according to ship type. The steel fraction will typically increase as complexity is increased and size reduced.

Copper represents a high value commodity and markets exist for recycling and reclaiming scrap copper. One of the major sources of copper in a ship is electrical cabling. Such cable is recycled by stripping off the insulated covering and other layers to recover the copper. Dedicated cable stripping machines exist for such tasks. The resulting copper can be sold as scrap and the insulation material would add to the relevant waste stream (most often this will be that of plastics, however, insulation may be consist of other materials). Alternatively the cable can be sold to an intermediary for such separation. Another main source of copper is from electric motor windings. Copper may arrive from the waste stream of electrical and electronic equipment. Copper pipework can be sold directly unless highly contaminated.

It is important to separate copper and other non-ferrous metals from the scrap steel, as copper is a major contaminant in the steel making process. Further, it may be required to treat insulation waste as hazardous waste as certain cable types have insulation components that belong in this category.

Special bronzes alloys used in e.g. the manufacturing of propellers are equally valuable and are sought after in the recycling market.

Anodes are fitted to both the vessel’s hull and inside tanks in order to protect against corrosion and fouling. Anodes consist mainly of aluminium (Al) and zinc (Zn), but may also include small amounts of other metals, such as Cu, Fe, and Hg. Anodes are sacrificed over a space of time and the amount of metals left when the ship arrives for scrapping will reflect its history of maintenance. Currently, anodes are often removed and sorted for reuse/ resale. Heavily corroded anodes are disposed of as waste, if recycling is not a feasible option. The removal of the anodes will in itself not generate any adverse effects on humans or the environment, since Al and Zn are non-toxic in their solid states (ref.:/19/).

Note that anodes should avoid being mixed with steel scrap as it represents a source for contamination in the steel recycling process.

6.2.3.2 Machinery

There are many items of machinery on board a ship, ranging from the main engine itself, through auxiliary generators to smaller items like pumps and separators. These items comprise mainly metal bodies, and specialist operators exist which will take machinery for recycling. If such machinery is free from fuel oils, lubrication oils, greases, etc. a potential revenue stream exists. However, if cleaning is required a charge or expense will be incurred. Discussions with recyclers indicate that cleaning would probably not be required for most ship machinery.

It is envisaged therefore that most ship machinery could be saleable for revenue. Once again the question of scale exists, ships' main engines in particular, are likely to be far larger than comparable items of machinery currently recycled, so it is envisaged that dismantling into component parts may be required.

6.2.3.3 Electrical and electronic equipment

At present, there is no existing scrap market for such items or specialist disposal operators. It is envisaged therefore that such items would represent a disposal cost to the process. However, as legislation evolves from the forthcoming Waste Electrical and Electronic Equipment (and other) directives, - it may well be that specialist operators will emerge for the disposal of such items. There is some evidence for this happening for computers.

6.2.3.4 Minerals

A wide range of mineral items exists on board ships, especially in the accommodation areas. In general terms, mineral materials are suitable for recycling into aggregates. However, in current market conditions, there would be a charge made for such material by a specialist processor or intermediary. Through use of an on-site crushing facility it should be possible to achieve a neutral cost stream and future changes in legislation may well turn this into a revenue stream. Specifically there are some mineral wastes that are classified as controlled or hazardous wastes for which specialist disposal would be required. These include mineral wool and insulation materials, which are classed as controlled wastes, but which may soon be upgraded to hazardous classification.

Asbestos-containing material (ACM) may be found in thermal system insulation and on surfacing materials. Some other applications may also be found. The use of asbestos in ship building may have continued into the 1980s despite the introduction of regulations already in place in the latter half of the 1970s. Regulations on asbestos and the SHE aspects of asbestos are elaborated upon in chapter 6.2.4.1.

6.2.3.5 Plastics

Increasingly, plastic materials are used in vessels, particularly in accommodation areas. Plastics used for example in furniture and fittings are likely to comprise of several polymers or to be contaminated with other materials such as textiles or metals, rendering them unsuitable for recycling. It is considered therefore that the majority of the plastic waste streams from vessels are generally going to require disposal for which a disposal cost is envisaged. Certain specific items such as cable coverings may be suitable for recycling, but this is likely to be the exception rather than the rule.

Polyvinyl chlorides (PVC) are used in a wide variety of products for different applications and are commonly found in cables, floor coverings and plastic devices of different types. PVC contains more than 50% chlorine, and may contain environmentally hazardous additives. A complex mixture of fumes and gases is generated when PVC is burned. This includes large quantities of hydrogen chloride gas that can react with water vapours and form hydrochloric acid in the lungs, as well as carbon monoxide, dioxins and chlorinated furans. Dioxins are among the most toxic substances known.

6.2.3.6 Liquids, chemicals and gases

Reclaimed fuels, hydraulics and lubricating oils have a residual value, however the costs of recovering/ cleaning these can be significant and is likely to offset any such revenue. It is envisaged that much of the liquid wastes could be processed in a conventional tank farm arrangement allowing the recovery of any oils through separation for re-use or resale by the yard. It has been assumed that these would be recyclable but without revenue or cost to the dismantling yard. It is unlikely that shipowners will deliver ships with significant volumes of uncontaminated fuels, and where these exist it is likely to be compensated for in terms of the negotiated price of the vessel.

Coolants and refrigerants can often be sold for re-use, but the equipment needed to recover these is fairly specialised and in low volumes it is likely that there would be a cost for the removal of these by a specialist operator. However, the introduction of regulations (MARPOL, Annex VI) may require such substances to be delivered to waste reception facilities.

The vessels piping and tank arrangements will generally contain some quantities of oil, fuel, sludge and associated residues. Fuel oil may be found in both integrated and free-standing tanks throughout the ship. Lubricating oils may be found in a variety of tanks depending on their individual use. System oils are typically located in engine room sump tanks, whilst cylinder oils may be stored in separate purpose tanks. Lubrication oils may also be stored in drums. Tankers may arrive at the scrapping facility with a significant quantity of cargo residues. Further, all tanks may contain a certain level of sludge.

The primary danger in handling oil and fuel on ships is that of fire. Still, it should be noted that oil and fuel represent certain toxic hazards. Both petroleum products and non-petroleum oils can have adverse and well documented effects on the environment. Note that local/ national requirements may require notification to authorities on installation as well as on use, including fire regulations for the storage of flammable or combustible liquids and further on financial responsibilities.

Used oil may be defined as oil that has been refined from crude oil or made from synthetic materials, and that contains physical or chemical contaminants as a result of being used. Used oil should not be mixed with other wastes as this may require the entire volume to have to be managed as hazardous waste. The most environmentally friendly and often most economical way of managing used oil is recycling. Oil and oily wastes that are defined as hazardous waste, either by definition (e.g. appearing on “target lists”) or by having hazardous waste characteristics (ignitable, corrosive, reactive or toxic) and must be managed according to governing national hazardous waste regulations.

Other chemicals requiring particular attention and affecting the requirements of the process and hence the revenue streams are:

- Glycol and water
- Different chemicals for injection
- Methanol for injection

- AFFF foam
- Dry powder in fire extinguishers
- Solvents/ thinners
- Battery electrolyte
- Evaporator dosing and de-scaling acids
- Corrosion inhibitor
- Fresh paints

6.2.3.7 Joinery related products

Where timber, wood and associated materials exists on a ship, this can generally be reclaimed and sold to intermediary resellers. However, in modern ship designs, much of the joinery products are of a composite nature and may be contaminated by vinyl, plastics, rubber, etc. It is likely that this would have to be disposed of at a charge, although wood recovered from shredding can generally be disposed of at no cost to recycling centres. An alternative to disposal is incineration, which can provide a low cost alternative energy source. MDF is not recyclable and would require disposal.

6.2.3.8 Miscellaneous

Bilge and ballast water

Bilge water is stagnant water mixed with potentially polluting liquids, that has drained to the lowest inner part of a ship's hull (i.e. the ship's bilge). Bilge water is often referred to as oily waste as it may contain oil and grease, in addition to other pollutants (inorganic salts, and metals, such as arsenic, copper, chromium, lead, and mercury). More bilge water may be accumulated through rainwater during ship scrapping.

Ballast water is fresh, brackish or marine water that intentionally has been brought on board a ship in order to adjust the ship's stability and trim characteristics in accordance to accommodate various operating conditions. Ballast water may contain pollutants, such as residual fuel, biocides, oil and grease, petroleum hydrocarbons, and metals (e.g. iron, copper, chromium, nickel, zinc). Ballast water in cargo tanks (oil) is often referred to as dirty ballast water.

Transport of large volumes of water containing organisms from shallow, coastal waters across natural oceanic barriers can cause massive invasions of neritic marine organisms. Because ballast water is usually taken from bays and estuaries with water rich in animal and plant life, most ships carry a diverse assemblage of organisms in their ballast water. Viable organisms isolated from ballast water discharges, include fish, crustaceans, molluscs, polychaete worms, arrow worms, coelentarates, sea squirts, toxic dinoflagellates, diatoms, virus and bacteria. Aggregated sediments typically found in ballast tanks will contain living species reflecting the trade history of the vessel. The discharge of ballast water/ sediment species into the coastal sea-area in the vicinity of, or at the scrapping site, may carry the potential of introducing unwanted organisms threatening the ecological balance in the seas in the area and thereby introducing a direct threat to biodiversity. Ballast water can be the source of viruses and bacteria transferred to humans causing epidemics (ref.:/29/).

The facility should determine the pollutant concentrations in bilge and ballast water prior to discharge. Further, the ecological aspects of ballast water discharge should be considered. Bilge and ballast water may be transferred to onshore storage tanks, evaporation pits (ballast water only) or discharged directly overboard. National discharge regulations may apply and may specify which pollutants to analyse for and provide permitted levels of the contaminants. In addition the MARPOL convention, Annex I, also provides regulations for permissible levels of oil in discharged ballast water. Discharge of ballast water should in general be avoided if not analysed and found not to represent an ecological threat. Note that additives, such as sodium chromate, sometimes are used for both ballast water and bilge water in order to prevent algal growth during a ship's operation. A high chromium concentration would make the ballast water hazardous waste. Ballast water sediments should be assessed equally and may consequently require to be handled as hazardous waste.

The cost assessment assumes that the handling of bilge water, ballast water and sediments represent a neutral cost element.

Freon

Freon (a Du Pont trade name for chlorofluorocarbons) (CFC), compounds of chlorine, fluorine and carbon, are nontoxic, nonflammable and stable in the troposphere, whereas in the stratosphere, they can be broken down by UV light and deplete the ozone layer. CFCs are used as refrigerants, solvents and foam blowing agents. Shipborne CFCs have been believed to contribute up to 10% of global emissions. The United States, Canada, and the Scandinavian countries imposed a ban on the use of CFCs in aerosol-spray dispensers in the late 1970s. In 1987, 27 nations signed the Montreal Protocol, which is a global environmental treaty on reducing substances that deplete the ozone layer. Several amendments have followed, and the use of CFCs, some chlorinated solvents and Halons (chemicals used as fire extinguishing agents) should therefore become obsolete in the next decade (ref.:/30/). These products and restrictions associated with their use are also addressed in MARPOL (Annex VI).

The handling of Freons represents a cost.

Paints and coatings

A comprehensive selection of different paints and coating products are present on board a vessel. These products are used both on the exterior and the interior and may have characteristics requiring certain precautions with respect to the demolition process. Paints can be flammable and may contain toxic compounds (PCBs, heavy metals (e.g. lead, barium, cadmium, chromium, and zinc), and pesticides). Paints with metallic compounds are used to protect ship surfaces from corrosion. Pesticides, such as tributyl tin (TBT) and organotin are still commonly in use on subsurface hull in order to prevent fouling. Fresh paint for maintenance purposes may also be found on board (see chapter 6.2.3.6).

Removal of paints prior to cutting during ship scrapping may not be necessary unless the process will lead to the release of toxic compounds or if the paint is highly flammable.

Paint follows the flow of steel and hence is "exported" to the steelworks away from the demolition facility. Measures including paint removal or emission cleaning may be required prior to or during recycling (at steelworks).

Batteries can contain heavy metals such as Pb, Cd and Ni. Lead-acid batteries also contain sulphuric acid, which is corrosive and can cause severe burns. There are batteries in flashlights, mobile radios and electrical equipment, but the largest volume of batteries (lead-acid batteries) is found in radios, intercom, fire alarms, emergency start equipment and lifeboats. Batteries in working order will most often be sorted and sold for reuse. Lead represents a considerable value in itself, and there is therefore reason to believe that the batteries could be recycled regardless of their condition. If batteries are undamaged, they will not have an environmental effect. However, improper disposal of batteries can cause a threat to human health and the environment (ref.: /19/).

6.2.4 Waste streams and SHE aspects

The extraction of materials as described under chapter6.2.3 introduces a number of issues of SHE-nature. Some of the onboard substances (integrated in products or systems) are harmful in themselves whilst the actual extraction process may introduce scenarios generating such substances. Further, workers safety is an item to be considered in all of the operations incurring during demolition.

6.2.4.1 Asbestos

Asbestos-containing material (ACM) may be found in thermal system insulation and on surfacing materials. Some other applications may also be found. When ACM is deteriorated or disturbed, asbestos breaks up into very fine fibres that can be suspended in the air for long periods and possibly inhaled by workers and operators at the facility or by people living nearby. The most dangerous asbestos fibres are too small to be visible. Once they are inhaled, the fibres can remain and accumulate in the lungs. Breathing high levels of asbestos fibres can lead to an increased risk of lung cancer, mesothelioma (a cancer of the chest and abdominal linings), and asbestosis (irreversible lung scarring that can be fatal). The risk of lung cancer and mesothelioma increases with level of exposure. Symptoms of these diseases do not show up until many years after exposure. Most people with asbestos-related diseases have been exposed to elevated concentrations in connection with their work.

When health hazards associated with asbestos were revealed in the late 70's, legislation on the use of asbestos was initiated. The US EPA regulation on asbestos dates back to 1989, but was amended in 1991 leaving only six asbestos-containing product categories subject to the asbestos ban (corrugated paper, rollboard, commercial paper, speciality paper, flooring felt, and new uses of asbestos). In addition, several uses of Asbestos Containing Materials (ACM) remained banned (spray-on applications of asbestos (> 1% asbestos) and certain types of asbestos-containing insulation). The European Commission imposed a ban on the remaining use of asbestos through the Asbestos Directive in 1991. This prohibits the use of 5 out of 6 types of asbestos. The remaining type (white, chrysotile) was banned in 14 categories of asbestos. A full and complete asbestos ban will enter into force across the EU no later than year 2005. It should be noted that a number of states around the world imposed strict regulations on the use of asbestos at a much earlier stage. Denmark was a pioneer in this area when a ban for the use of asbestos was introduced in 1972. Sweden banned marketing of certain asbestos products in 1975 and followed up by a product ban in 1976 (crocidolite, or blue asbestos). The Netherlands followed in 1977 and then a string of nations revealed new stricter regulations on marketing, manufacturing and the use of different asbestos products.

Asbestos removed from a ship is still not necessarily regulated as hazardous waste. In fact, in some countries asbestos is recovered by manual crushing and then re-casted for re-use (ref.: /20/). Depending on national regulations, the scrapping facility must accommodate to whatever requirements there may be. However, the potential health impacts associated with the use of asbestos are of such severe nature that minimum precautions are necessary. This includes the protection of workers when extracting asbestos from the vessel, the securing of the disposal of asbestos and measures preventing asbestos to re-enter the market. If national requirements do not address these areas, the facility is recommended to implement an asbestos disposal plan in the waste management plan. This should include requirements associated to the ship's inventory plans so that asbestos can be localised, quantified and identified prior to removal. Further, the plan should identify personal safety equipment for personnel removing the material and procedures for both the removal as well as the disposal. Handling of asbestos should be monitored by record keeping as well as by sampling. The facility is advised to refrain from selling asbestos to re-enter the market.

All ACM must be removed from a ship being scrapped before any activity that would disturb the materials is carried out. Processes producing asbestos dust must be isolated. To prevent dispersion of dust and debris containing ACM, control methods, such as vacuum cleaners and/ or local exhaust ventilation equipped with HEPA filters must be used. The ACM to be removed must be adequately wet when removed and must remain wet until it has been collected and contained (in leak-tight containers) for disposal, unless the material is contained in leak-tight wrapping. The ACM should then be carefully lowered to the ground. Properly labelled leak-tight containers with lid are required to be used for the transport of asbestos from the extraction site to the disposal area. Typically, asbestos is disposed of by burying it in the ground.

Asbestos may be found in considerable amounts on board. Sampling has revealed quantities in the region of 7 – 11 tons for vessels in the size category 100,000 – 250,000 dwt. It should be noted that vessel size is not necessarily decisive for heat insulation requirements.

6.2.4.2 PCBs

PCBs are found in a variety of equipment and materials including cable insulation, thermal insulation material, transformers, capacitors, oils, paints, plastics and rubber products, etc. PCBs are toxic and persistent in the environment and have been shown to cause a number of adverse health effects. The toxicity of chemicals produced when PCBs are heated (polychlorinated dibenzofurans and polychlorinated dibenzo-p-dioxins) is of special concern, as they are believed to be even more toxic than PCBs themselves.

Transformers are either oil cooled or air-cooled. An offshore unit platform will on average have one oil cooled transformer. The oil in the transformer may have*PCB-containing oil*. Sometimes this oil has been changed during maintenance, and hence the PCB-containing oil may have been replaced. It should be noticed that there might be traces of PCB in the changed oil.

PCB has been found in various concentrations in cable insulation by independent investigations (see section 6.2.3.1, and ref.: /20/ and /24/). Recently revealed maximum PCB-concentrations from cable samples taken from vessels during scrapping at 280.000 ppm (28%) is alarmingly high. Based on this, it seems reasonable to suggest that the configuration of cable insulation arriving from vessels being decommissioned will most likely contain PCB in some quantities. Improper processing of cables in order to extract copper by burning off the insulation (commonly used in scrap facilities in Bangladesh and India) may lead to the release of particularly hazardous components to the environment and must be avoided.

The production of PCBs in the USA ceased in 1979 following new regulations. In Europe, most countries banned the manufacturing of PCB in the early 1980s (1978-1982) and phase-out regulations on use of PCB are in place. A global campaign aiming at prohibiting all use of PCB is ongoing. International trade of PCB is regulated in the Rotterdam Convention.

Wastes containing PCBs at a concentration level of 50 mg/kg or more are considered hazardous waste by the Basel Convention. As a precaution, it may be feasible to remove all known and suspected PCBs and PCB-containing material, or conduct sampling and chemical analysis of these items and, if regulated PCB levels are present, dispose of them according to relevant national regulations.

PCBs or PCB items to be stored must be placed in proper containers, covered and labelled according to the relevant regulations. PCB-containing waste may be disposed of by incineration (licensed) or at special landfills. Disposal requirements may be dependent upon the nature of the source and its concentration.

6.2.4.3 Radiation sources

Radioactive material may be present on board a ship in liquid level indicators, smoke detectors or emergency signs. These sources generate low-level radioactive waste, but handling and disposal of such waste is usually strictly regulated. Ionising radiation is hazardous to human health and the environment and can cause severe forms of cancer and/ or damage to genetic material endangering future generations. Any release of radioactive material could increase the radiation exposure to the population and must therefore be avoided.

Radioactive deposits, often referred to as low specific activity (LSA) scale, formed inside vessels and pipework, is a well-known problem on oil production facilities. These deposits contain elevated levels of radioactivity, mainly ^{226}Ra, ^{228}Ra and their daughter products, however the exact concentration and composition of the radionuclides in the scale varies with the source rock and the extraction depth of the oil.

The radium is tightly bound to the lattice structure of the Ba/Sr/Ca SO_4 and $CaCO_3$ in the scale. Of the radionuclides present in the scale in significant concentrations, ^{226}Ra has the longest half-life of 1,620 years. The remaining nuclides have considerably shorter half-life, most of them from days to seconds, and because of the slow transfer rates to surface water relatively high levels could be introduced to the sea without any measurable effect at greater distance from the source. However, release of ^{226}Ra could potentially lead to increased dose rates to man through e.g. consumption of seafood. Radionuclides are naturally present in the aquatic environment, and all aquatic organisms have evolved and developed in the presence of a background radiation exposure. Human activities have resulted in the introduction of additional quantities of radionuclides into the marine environment. The radionuclides present in LSA scale are of natural origin and therefore indistinguishable in kind, but not necessarily in quantity from those naturally present in the marine environment.

The water solubility of scale is very low, and it is estimated to be 6.5 x 10^{3} % in distilled water. It is also estimated that it will take 800 years to dissolve a 1-cm layer of scale. Because of this low solubility, the dissolved scale will be very diluted, and it is assumed that an effect of radioactivity only will be relevant in the vicinity of the scale deposits.

It is recommended that as much LSA scale as possible is removed prior to platform removal/ dismantling (ref.: /31/).

6.2.4.4 Mercury

Mercury is a toxic heavy metal and a persistent, bioaccumulative pollutant that affects the nervous system. On board ships, mercury can be found in thermometers, electrical switches and light fittings. Accidental spills of mercury can lead to dangerous mercury exposure.

Consumption of contaminated fish is also an important route of mercury exposure. Mercury must be handled as hazardous waste according to national regulations.

6.2.4.5 Isocyanates

These are often used in spray-painting and polyurethane coating processes and may be released when hot work is applied. Occupational exposure can cause respiratory diseases and asthma. The exposure levels likely to be generated by ship scrapping activities are unknown.

6.2.4.6 Tributyl tin (TBT)

Tributyl tin (TBT) is an organometallic substance used in anti-fouling paints. It can cause an effect at low to sub-nanogram quantities per litre, and is therefore considered to be one of the most toxic compounds in the aquatic environment. Its use is now strictly controlled in most parts of the world (ref.: /32/). A study looking at the distribution of TBT in Asian waters showed highest values in areas with high shipping activity (ref.:/19/).

6.2.4.7 Lead (Pb)

Lead is toxic, and is found in batteries, paints and in components in motors, generators, piping, cables and others. The deleterious effects of lead upon human health have been commonly known for a long time. Young children are most susceptible to the toxic effects of lead. Long-term exposure to even low levels can cause irreversible learning difficulties, mental retardation and delayed neurological and physical development. In adults, exposure to lead affects primarily the peripheral nervous system and can cause impairment of hearing, vision, and muscle co-ordination. Lead also damages the blood vessels, kidneys, heart and the reproductive system.

An investigation at four ship-breaking operations in Canada revealed widespread excessive lead exposure to employees. Air sampling results for lead were above recommended standards at all locations. Another study conducted on workers from a scrapping/ shipyard in Taiwan showed that the workers involved with steel cutting have higher lead values in blood and urine than the dock workers. The study involved 140 oxyacetylene torch metal burners and 21 dock workers without direct lead exposure as the control group.

Lead chromate (present in paint pigments) is documented as a carcinogen both to humans and other organisms. It may also damage embryo development and cause infertility.

Improper disposal of batteries and paints containing lead can cause a threat to health as well as to the environment (ref.: /19/).

6.2.4.8 Marine growth

This constitutes a large amount of sessile organisms that grow on the jacket of offshore installations and represents waste that has to be treated onshore. The amount of *marine growth* varies depending e.g. on the water depth.

6.2.4.9 Other waste streams

In instances where no recycling option is available, waste materials would potentially be designated for disposal. Two main options exist in the general recycling industry landfill and/or incineration. Comments in chapter6.1 however explain that landfill options are likely to become more expensive and increasingly prohibited in an attempt to reduce landfill activity and promote recycling

6.2.4.10 Extraction procedures, hazardous substances and SHE-exposure

There are obvious SHE-issues requiring attention within ship scrapping. Some precautions that may contribute to improve general SHE-aspects within the ship scrapping industry are briefly summarised in Table 6-4. This listing is meant to highlight the issues of SHE and is not a guide for ship scrapping facilities.

Table 6-4 General SHE aspects within the ship scrapping industry (ref.: /28/)

Dismantling activity	Workers exposure	Measures	Environmental exposure	Measures	Safety exposure
Asbestos removal and disposal	Exposure to asbestos fibres, especially through inhalation, may cause asbestosis or cancer.	• Approved respirators • Protective clothing • Head covering • Gloves • Foot covering • Face shield/ goggles • Decontamination areas and procedures	Exposure of people working and living in the neighbourhood, and migration of asbestos fibres to bodies of water.	• Wet asbestos/ misting • Regulate area for removal • Prompt cleanup and disposal • Containment in leak-tight wrapping • Exhaust ventilation equipped with HEPA filter • Enclosure of processes producing dust	
PCB removal and disposal	Exposure through inhalation, ingestion, or absorption through the skin may cause adverse health effects.	• Protect from exposure to airborne PCBs in the workplace • Appropriate personal protective clothing or equipment, depending on removal and disposal scenario • Respirators, if necessary	PCBs are toxic and persistent in the environment. The most carcinogenic PCBs tend to bioaccumulate.	• Sampling, PCB conc. > 50 ppm is hazardous waste • Proper storage facilities • Labelling and segregation of PCB-containing waste • Proper transportation and disposal	Toxic furans and di are produced when PCBs are heated, f.e fire-related incident
Bilge and ballast water removal	Toxic organics, i.e. solvents or PCBs, may cause serious health effects. Discharge of toxic organics may cause release of poisonous gases.	• Careful cleaning before any hot work • Ventilation of tank/ compartment and testing for vapours and oxygen before entry • Training	Metal exposure: consumption of contaminated seafood may cause health problems. Oils and fuels may poison marine organisms and physically soil the environment (birds, fish, plants, etc.). Invasion of alien aquatic species that may disturb the ecological balance.	• Test for pollutants (i.e. chromium) • Proper transfer equipment and booms • Proper storage and disposal, dependent on contamination level • Discharge permit or proper pretreatment, if required • Management plans for oil spill prevention, response and recovery	Flammable vapours gases may evolve fr residues in tanks or compartments.

Table 6-4 Continuing..

Dismantling activity	Workers exposure	Measures	Environmental exposure	Measures	Safety exposure
Oil and fuel removal	Oils and fuels may exhibit toxic characteristics. Main exposure routes are inhalation and consumption of contaminated fish and water.	• Careful cleaning before any hot work • Ventilation of tank/ compartment and testing for vapours and oxygen before entry • Training	Oils can have adverse effects on the environment, f. example by physical damage of wildlife and their habitats. Light refined petroleum products are toxic and represent a fire hazard. Oil spill threatens natural resources, birds, mammals and marine organisms.	• Proper transfer equipment and booms • Meet national storage and disposal requirements • Management plans for oil spill prevention, response and recovery	Refined petroleum products represent a hazard.
Paint removal and disposal	Chemicals/ solvents used in stripping evolve VOCs and hazardous air pollutants. Abrasive blasting and mechanical removal generate particulates (i.e. lead dust). These emissions are toxic and may cause cancer. Main exposure route is inhalation.	• Appropriate personal protective equipment, incl. respiratory protection, and often eye and skin protection • Test paint/ coating for toxicity and flammability, and remove prior to cutting, if necessary • Blasting equipment must be regularly inspected	Wastes (incl. blasting residues and paint chips) may have negative effect on the environment through contamination of soil and surface waters.	• Proper management and disposal of waste from removal of paint/ coating • Measures to prevent or minimise pollution of runoff water	Paints and coatings be flammable.

Table 6-4 Continuing…

Dismantling activity	Workers exposure	Measures	Environmental exposure	Measures	Safety exposure
Metal cutting and metal disposal	Torch cutting generates fumes, smoke and particulates (incl. manganese, nickel, chromium, iron, asbestos, and lead) that may have toxic effects.	• Make sure area is tested and declared safe for hot work prior to cutting • Workers must use suitable eye, hand and body protection • Respiratory protective equipment and/or ventilation under certain circumstances • Clothing must not contain flammable material • Noise protection • Careful handling of compressed gas cylinders • Training	Improper storage and disposal of scrap metal and wastes from cutting processes may contaminate soil and water. Environmentally hazardous fumes may evolve when metal and/or paint is heated, f.ex. during hot work.	• Remove toxic or flammable coatings prior to cutting • Fluff from shredding must be stored and disposed of in accordance with regulations • Cable burning in open air may be prohibited • Wastewater from cutting operations must be properly managed • Scrap metal that is not recycled must be properly managed and disposed of	Pockets of flammab substances represen fire and explosion hazard when cutting metal.
Removal and disposal of miscellaneous ship machinery	Workers handling ship machinery components may be exposed to contaminants, such as asbestos, PCBs, oil and fuels.	• See protective measures from processes above	Ship machinery components may be contaminated with hazardous materials, such as asbestos, PCBs, oil and fuels. Improper storage may also lead to lead contamination.	• Ship machinery components must be handled, stored and reused/ recycled/ disposed of in an appropriate manner to avoid contamination of soil, surface water and groundwater	Oils, fuels, etc. may represent a fire and explosion hazard wl being disassembled

6.2.5 Waste stream summary

An attempt has been made to quantify the main waste streams discussed in the subchapters 6.2.3 and 6.2.4. These results are presented in Appendix B.

In order to estimate volumes for the merchant fleet, "standard vessels" representative of the forecasted scrapping demand (chapter 4.3) have been identified. These are presented in Table 6-5.

Table 6-5 Dimensions of the "standard vessels" used for estimating waste stream volumes for the merchant fleet.

Vessel type	**Dwt.**	**Light.**	**W_{st}**	**W_{mach}**	**W_{out}**	**W_n**
Standard tanker (type 1)	120,000	21,487	15,998	1,059	3,762	668
Standard bulker (type 2)	52,000	15,158	9,562	889	2419	2288

Lightship weight (light.) has been estimated based on data from approximately 20 vessels (for both types and size-groups). The steelweight (W_{st}) has been calculated based on empirical approximations (ref.: /36/). Machinery weight (W_{mach}) include main propulsion engine(s) and associated systems whilst generators, auxiliary engines, etc are included in a system weight group (W_n). W_{mach} and outfit weight (W_{out}) are calculated based on empirical approximations (ref.: /37/) using input data (power, length and beam) from the same source as the lightship calculations.

The waste streams (Table 6-3) have been quantified by assessing the relative composition of each of the three main weight categories of the ship: A (steelwork/ outfit), B (machinery outfit) and C (joinery/ outfit) using data from the type 1 and type 2 vessels (see Table 6-5) and proportion numbers derived from sample vessel (presented in Appendix B). Distribution between the categories (ABC) reflects the findings presented in Table 6-2. Note that there is room for considerable variation in these proportion numbers depending on ship type and size. The results are presented in Table 6-6.

Table 6-6 Waste stream quantification in the A, B, and C categories

	Total		**Type A**		**Type B**		**Type C**	
	%		**%**					
Waste Stream	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2
Steel (f)	*74.4*	*63.15*	55.8	47.35	9.3	7.9	9.3	7.9
Copper (nf)	*0.01*	*0.04*	0.01	0.02	0	0.01	0	0.01
Zinc (fn)	*0.03*	*0.04*	0.03	0.04	0	0	0	0
Special Bronze(nf)	*0.03*	*0.04*	0	0	0.03	0.04	0	0
Machinery	*14*	*19*	5	8	9	11	0	0
Electrical/Electronic Equipment	*2.5*	*5*	0.5	1.5	1.5	2.5	0.5	1
Joinery - related products	*5*	*6*	0	0	1	2	4	4
Minerals	*0.5*	*2.5*	0	1	0.4	1	0.1	0.5
Plastics	*0.5*	*1.2*	0	0.1	0.1	0.5	0.4	0.6
Liquids	*2*	*1*	1.5	0.5	0.5	0.5	0	0
Chemicals and gases	*0.03*	*0.03*	0	0	0.03	0.03	0	0
Other miscellaneous	*1*	*2*	0.5	0.75	0.5	0.75	0	0.5
Distribution, segments	100	100	63.34	59.26	22.36	26.23	14.3	14.51

6.3 Market for product categories from scrapping processes in Europe

6.3.1 Re-use, recycling and disposal options

The general environmental hierarchy comprising reuse, recycle and disposal, may only have partial application for ship scrapping in the European context. The options on recycling for some of the relevant items or substances are fairly limited.

The environmental context is changing rapidly and legislation is being implemented or introduced to require more recycling and to reduce disposal by landfill. As a result, specialist operators are emerging to deal with certain types of waste that has previously been considered uneconomic to recycle. As technology evolves in such areas, the economics change, there may still be a cost to the originator of the waste but this may start to drop or even turn into a revenue stream. Most importantly, it reduces the volume of material destined for landfill, which is likely to be restricted by legislation and hence become increasingly expensive as a disposal route.

One example of how these developments are taking shape, is the form of recycling villages, comprising a wide variety of specialist operators present on a single site to deal with large quantities of potentially recyclable wastes. Clearly, the location of such a facility close to a ship dismantling facility would be very desirable to maximise the opportunities for recycling waste on the best economic basis.

In terms of re-use, the existing climate allows for little or no re-use of components from ships and major changes in legislation and culture would be required before such options are likely to exist. In such circumstances, the approach to design and procurement in ship newbuilding would need to adjust to reflect this. However, at a more fundamental level, the options for re-use may seem closer. Firstly, the trend of recent years to refurbish cruise ships rather than to replace, can be seen as the re-use of the ships hull and structure. More dramatically, conversions of ships to new functionality are other examples of reuse of the elements of the ship. The conversion of tankers into FPSOs can be seen in this context. In the offshore market the re-use of platforms has already been adopted in some instances.

Another area in which there has been some interest recently, is in the replacement of the forebody of ships to provide new cargo carrying functionality. This in effect is the re-use of the engine room and accommodation areas once the condition or the functionality of the cargo section has deteriorated to uneconomic levels. The vast majority of non-steel elements of the vessel, lie in these two areas and this is where much of the non-recyclable waste is generated. Development in this area, therefore, would offer a major option for re-use of ship components.

Those operators adopting or exploring such options clearly see an economic argument for following such initiatives. However, at the present times, these occur against the current climate of selling vessels for scrap to the traditional scrapping sites or to other operators who will take account of the eventual disposal value of the vessel. Environmentally, there has been little impact on either operators or builders in terms of legislation requiring recyclability of the product in terms of controlled or restricted disposal. If the end of life value of the vessel reduces or turns into a cost rather than a revenue, it will shift the economic balance to favour re-use conversions rather than newbuildings. In such circumstances, technological and design changes will start to emerge. Additionally, there may be an impact at component level for example the economics of technical obsolescence will alter when there are either restrictions or major cost implications on disposal.

The future may bring forward significant issues regarding the re-use of ships and their components that will be triggered by the changing environmental context and legislation. The realisation of such opportunities will be dependent upon “design for re-use” criteria becoming part of the design requirements for ships along with other environmental requirements.

Following the decision of decommissioning, independent of vessel category, specific equipment, installations and components will be removed and excluded from the actual scrapping process. In some cases, this is commonly carried out prior to sale and hence these articles do not follow the vessel to its final destiny. This will be the case for offshore structures and naval vessels to a greater extent than it will be for the world merchant fleet and for inland waterway vessels. These components may be kept by the original owner and installed onboard other vessels in the fleet or the owner may offer these for sale.

Consumable stores will also be removed before demolition and offered to the market directly. Some “system consumables” such as fuels and lubrication oils may also be removed at this stage and offered either directly to the market or for recovery (see chapter 6.2).

6.3.2 Products

Re-usable products may be equipment, components, systems, substances, and consumables of sections or whole installations/modules (offshore). Some examples are listed below.

- Whole operational offshore installations (the whole installation including jacket and topside or e.g. subsea templates)
- Whole offshore modules (e.g. quarter module, compressor module)
- Structure (i.e. de-polluted ship hull)
- Compressors
- Generators
- Pumps
- Machinery including diesel engines and turbines
- Hydraulic components
- Cranes
- Electrical equipment (e.g. navigational aids (radars, etc.), radios, computers, televisions)
- Life saving equipment (e.g. life rafts/ boats, survival suits, life buoys)
- Drilling equipment (e.g. drilling pipes)
- Sanitary equipment
- Oils and chemicals (lubricating oil, drilling chemicals, operational chemicals, etc.)

The main commodity arriving from traditional scrapping of merchant vessels, steel, is not addressed in the following.

6.3.3 Markets

In theory (and also in current practice), recovered products following demolition may find a new life also outside the original application. The supply of reconditioned products is in some industries quite common. Further, the second hand market characteristics will vary geographically reflecting the social standards and product legislation. At the present time, the practice seems better accepted within the offshore sector than in the merchant or other vessel sectors. The following sections provide some details.

6.3.3.1 Offshore installations

Sale and reuse of whole or parts of decommissioned offshore installations and equipment in the North Sea has been most unusual and nearly a non-subject until recently. In the Gulf of Mexico however, reuse is well-known and may be looked on as an established practice. Experience shows the potential of significant field development savings based on reuse. A reduction in investments in the region of 15-75 % compared to “new price” has been achieved. Many of the installations in the North Sea are older and much larger than the ones in the Gulf of Mexico and this will obviously represent a market limitation and impose an impact on the possibility of reuse (ref.: /27/).

Phillips Petroleum Company Norway (PPCoN) has in the recent years worked with the sale of offshore installations from the Ekofisk field. This field was closed down in 1998. PPCoN have established a web-page where 15 offshore installations are advertised for sale (ref.:/25/). The company has also been in dialog with the market through other operators and through purchasers of second hand equipment. The market response to these efforts has been limited. However, for certain equipment categories, in particular turbines and generators, there has been some interest in the international market.

Similar initiatives have been carried out by other operators;

> Elf Petroleum Norge (operator of the East Frigg, Lille Frigg and Frøy fields) initiated a process in connection with decommissioning of offshore fields in 1998 aiming at identifying reuse alternatives for their obsolete installations
>
> Statoil Norway have recently awarded an exclusive contract to Web Platform Brokers to take care of all marketing activities in connection with the marketing and sale of the Statoil 2/4S Riser platform.

WEB Platform Brokers operate an Oracle based database containing detailed records of offshore platforms, due for decommissioning within the next 5 years. ELF and Statoil have contracted this company in their attempt to find a second hand market in connection with decommissioning. PPCoN has launched their own system as mentioned earlier. The WEB Platform Broker system reveal platform specific details including production figures, uptime, PFD's (Process Flow Diagram's), equipment data sheets and maintenance records. In addition, a photo library offering 360º (bubble view) photographs of the platform's facilities are available.

Operators can, at their convenience, enter production requirements of new reservoirs and the software will match these production requirements with the capabilities of existing platforms in the database, highlighting potential benefits. The matching results will list the top three platforms with closest match to the production requirements of the new reservoir. Access to the database and the matching facility is possible via Internet. The service is free of charge for general search. A subscription is required fully detailed analysis.

The offshore second hand market is dominated by the companies within the offshore sector (i.e. other oil companies). Further, PPCoN has made donation agreements with four different organisations close to Stavanger for typical redundant equipment and movables, e.g. emergency batteries and lifeboats. These are all charity organisations. The company reports a number of enquiries originating from private individuals but these are refused on policy grounds.

6.3.3.2 Vessels

Current ship scrapping (naval, merchant, inland waterways) include beside “breaking” the ship and selling scrap metal for profit, recovering equipment for use in alternative environments, and perhaps even sinking an intact ship off a coast to be used as a reef.

A scrapping candidate found obsolete for its original intended purpose may have deficiencies associated to general condition, non-compliance with regulations or non-compliance with market requirements. There is an obvious difference between decommissioned offshore structures, which may be exported for reuse at a new field, and a decommissioned vessel. The latter is heading for a final destiny, since it has reached a point of no return in the sense of it being an operational vessel. The exception being some categories of naval vessels, which may be laid up over a long period of time before finally being scrapped.

Cargo carrying vessels consists comprehensively of steel structure, typically 60% – 90% of its lightship depending upon type and size and of components and systems. The composition of components varies in type and capacity dependent upon the specifics of the vessel. On board systems provide required functions and comprise a number of components. During the life span of the vessel, components and systems may be upgraded and replaced. Consequently, some components may be significantly younger than the vessel itself. Further, a vessel carries a substantial amount of spares. These may even be unused. Most often these are machinery spares. Based on this, it is likely that a certain market is available for secondary equipment and components.

However, the introduction of stricter regulations, certification requirements etc. will most likely make the re-use of shipboard components very limited for the European market. There may be some opportunities in the existing reconditioning markets, however, the potentials for re-use of such components as seen in developing countries will not be available unless the components are exported. This is most likely not cost efficient.

6.3.4 Potential barriers

There are a number of possible barriers affecting the potential for used/ second hand installations or equipment. Trade barriers such as taxes and duties are one of these (ref.: /26/). The issue concerning duties and taxes when importing second-hand equipment from the offshore sector/ shipping clearly represents a “grey zone” and regulations may differ between countries.

Both national regulations and international agreements will affect the opportunities (ref./26/). This may be illustrated by the following examples relevant for the offshore sector:

> **National regulations;**
>
> The Petroleum Act which regulates general aspects of petroleum activities, including exploration, production, liability for pollution damages, economic compensation to fishermen, safety, etc.
>
> The Pollution Control Act applies to pollution and waste in the external environment and subject to limitations following from international law. A number of regulations are laid down in pursuance of this act e.g. Regulations on hazardous waste, Regulations on dumping and incineration of substances and objects at sea, Regulations concerning export and import of hazardous waste, Regulations relating to notification of discharge of oil or oily mixtures to sea, rivers or land, Regulations concerning environmentally harmful batteries and

accumulators, Regulations concerning polychlorinated biphenyls (PCB) and Regulations concerning manufacture, import, export and use of chlorofluorocarbons (CFCs) and halons.

Act on worker protection and the working environment.

International agreements:

Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone (IMO) which regulate the removal of offshore structures in relation to safety of navigation.

The Geneva Convention on the continental shelf, which in its article 5 stipulates that any installation that is abandoned or not in use should be entirely removed.

The Ministerial Declaration of the Third International Conference on the Protection of the North Sea (The North Sea Declaration) which adopt a comprehensive set of common actions including reducing the input of hazardous substances and nutrients, the operational discharges from offshore installations and the discharges and disposal of radioactive wastes.

In addition there might be barriers with regard to *re-certification or re-qualification* (i.e. CE mark legislation). Used ship equipment to be used in Europe is subject to prove conformity with reference to CE-mark requirements. The second hand market will require “full” product documentation. This may induce design documentation and documentation of in-service performance and maintenance work. Re-certification of such equipment will be a stepwise process where the next step is determined by the results of the previous step in terms of technical and economical considerations.

Changing requirements in regulations is also a factor to be taken into account when assessing implications of re-certification. Thus the equipment will not meet the requirements that are used on today’s equipment.

Mental barriers will also affect the re-sale potential. The brokers in the market are willing to and eager to provide the market with used equipment. However, designers, owners and engineers are often unmotivated to consider second hand systems in new-building.

Moral ethic barriers may also occur. It is a possibility to sell second hand equipment to developing countries where this equipment may be of interest. However, moral ethic questions may be raised regarding export of such equipment. Why should the developing countries use this equipment when it isn’t found useful in the industrialised countries?

The above mentioned barriers will apply for all the types included in this study i.e. offshore installations, merchant vessels, navy vessels and inland waterway vessels. However it should be mentioned that e.g. navy vessels and the equipment included in these are built based on stricter rules than merchant vessels. Thus the equipment onboard navy vessels will suit a much smaller market than the equipment onboard merchant vessels.

7 SCRAPPING CAPACITY AND FUTURE VOLUMES

7.1 Scrapping Capacity

The capacity of current ship demolition and scrapping facilities is difficult to establish. The majority of existing ships scrapping sites are “first generation facilities” since they require only a suitable beach and a sufficiency of labour. They mostly rely on dynamic beaching as the means of transferring vessels from sea to land.

Current locations therefore have no real physical limits on expansion, capacity ultimately depending on how long the beach is and how many workers can be attracted to work there. The only constraint that may exist would be local planning and environmental concerns that might at least prevent uncontrolled expansion.

Demand is therefore considered the best measure of existing capacity and, in general, capacity does match demand. The best way to determine the present capacity therefore is to review the number of vessels and tonnage scrapped world-wide over recent years in the dominant merchant vessel category. This is summarised in the following table based upon the analysis of ships sold for scrapping in chapter 4, Table 4-5, with a provision for (merchant) vessels below 10,000 dwt scrapping workload. World scrapping capability, on this basis is therefore considered to be approximately 21.4 million deadweight.

Table 7-1 Tonnage (dwt) sold for scrapping in the period 1994-1999

	Million Deadweight						
	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**Ave**
>10,000 dwt (96%)	20.6	15.3	18.0	14.7	23.8	30.8	20.5
<10,000 dwt (4%)							0.9
Total							**21.4**

Exceptions are the vessels for which either no suitable facilities exist or there are political concerns over the potential future uses of the vessel or over the methods to be employed for their disposal. Offshore structures, naval vessels and other specialist vessels are typically representatives of such.

However there is increasing evidence of inadequate supply of facilities considered suitable to handle naval vessels and evidence of an increased number of abandoned vessels (e.g., on the west coast of Africa) or vessels being laid up.

In terms of location, during the last few decades, the focus of scrapping activity has changed as shown in Table 7-2. A variety of factors have influenced this movement, including general global development patterns, labour costs, scrap steel demand and regulatory developments (ref.: /18/).

Table 7-2 The movement of scrapping centres over the last 50 years.

Period	Main ship scrapping centres
1945- 80:	USA and Europe
1980-88	Korea, China and Taiwan
1980-98	India, China, Pakistan and Bangladesh

Current locations undertaking ship scrapping, have varied slightly in the recent past, with the following major locations being active in the last 10 years:

- Turkey (Izmir)
- India (Alang/ Bombay/ Calcutta/ Cochin)
- Pakistan (Gadani Beach)
- Bangladesh (Chittagong)
- Thailand (Sri Racha)
- Taiwan (Kao Hsing)
- China (Shaghai province)
- Vietnam

A number of other countries have a limited activity in this area.

Korea was active up to the late 1980's, the Philippines, Singapore and Indonesia do some work but are considered expensive. The USA has had poor results with various programmes to try to manage the scrapping of naval ships.

India, Pakistan, Bangladesh and China contributed to 65% of the scrapping activity in 1989, while the same countries handled 94% of the scrapping activity in 1998 (ref.:/11/, /21/ and /22/).

China was a dominant ship breaker in the 1980s. Following the introduction of national import fees on ships designated for the breaking yards, a severe decrease in volume going to China was experienced. Due to recent changes in the Chinese tax-system, the effect of this is no longer so visual and hence, China is seen re-entering the market of ship breaking.

India reached the position of major scrapping nation of the world in 1998 demolishing 370 ships of 6.3 million GT. This represented more than 50 per cent of all vessels scrapped in the year in terms of GT. In total China scrapped 30 vessels of 0.6 million GT compared with the 5.5 million GT scrapped in 1993. Bangladesh became the second ranked demolition country in 1998, with a turnover of 63 ships of 2.6 million GT. Pakistan demolished 57 vessels of 2.2 million GT and became the third largest scrapping nation in 1998 (ref.:/15/).

In terms of European vessels, the locations of known scrapping activity in 1999 is shown in Table 4-4 on page 23 in this report, from which it can be seen that India, Pakistan and Bangladesh have featured highly.

7.2 Future Scrapping Volumes

The future demand for ship scrapping over the next 15 year period has been identified in chapter 4, Table 4-7 and Table 4-8, of which the dominant element is merchant ships, comprising an annual scrapping projection of:

Table 7-3 Forecasted annual average of European ship scrapping volumes (2001-2015)

Vessel Size	OECD Europe		Geographical Europe	
	Dwt (million)	No	Dwt (million)	No
> 10,000 dwt	3.54	75	9.11	174
< 10,000 dwt	0.77	32	1.98	73
Total	**4.31**	**107**	**11.09**	**247**

Using the composition ratios identified in section6.1 this equates to the following projected throughput for a European ship scrapping facility:

- No of Ships : 107 - 247
- Deadweight : 4.31 - 11.09 million tonnes
- Gross Tonnage : 2.87 - 7.39 million tons (Dwt/1.5)
- 'A' Steelweight: 0.86 - 1.48 million tonnes (Dwt*0.2)
- 'B' space outfit : 0.14 - 0.25 million tonnes (Lightship * 0.125) **
- 'C' space outfit : 0.14 - 0.25 million tonnes (Lightship * 0.125) **
- Lightship : 1.15 - 1.98 million tonnes (Steelweight/0.75)

** Based on the average vessel composition in chapter6.2.1.

Based on the major waste stream categories identified in section6.2 and the composition ratios of these, this equates to the following waste material output streams:

Table 7-4 Forecasted annual waste stream volumes

Waste stream	Volume (tonnes)	
	OECD Europe	Geog. Europe
Steel	860,000	1,480,000
Copper	115	197
Zinc	345	591
Special Bronze	345	591
Machinery	161,000	275,800
Electrical/Electronic Equipment	28,750	49,250
Joinery – related products	57,500	98,500
Minerals	5,750	9,850
Plastics	5,750	9,850
Liquids	23,000	39,400
Chemicals and gases	345	591
Other miscellaneous	11,500	19,700
Total	**1,154,400**	**1,984,320**

7.3 Vessel Sizes

The size range distribution of vessels to be handled has been built upon the composition of the existing world cargo carrying fleet. These vessels represent the largest vessels in terms of size and the dominant composition in terms of overall tonnage and can be summarised as:

Table 7-5 World merchant fleet vessel sizes

Dwt size range	% by number	% by deadweight
0 – 10,000 dwt	69.9	10.0
10,000 - 40,000 dwt	18.2	24.5
40,000 - 100,000 dwt	8.5	30.0
100,000 - 300,000 dwt	2.8	29.7
300,000 – 400,000 dwt	0.2	4.4
400,000 + dwt	0.1	1.4
Total	**100.0**	**100.0**

8 SHIP DISPOSAL WITHIN EUROPE

On the basis that the existing capability and capacity for ship scrapping lies outside OECD Europe, is extensively non-compliant with respect to SHE criteria and is outwith the effective control of member countries and likely in opposition with the intentions of international conventions, a disposal facility for the hazardous aspects of ships from OECD/EU Europe needs to lie within Europe, one can argue.

This can be achieved either by the provision of pre-processing facilities to "clean" the vessel prior to disposal at existing facilities or the development of environmentally compliant facilities within Europe. Such facilities might be developed either around existing shipyard facilities (brownfield sites) or through purpose built new facilities (greenfield sites). These options are explored within the following sections.

8.1 Pre-processing

Pre-processing of vessels destined for scrapping, before despatch to the scrapping facility, requires the removal of the contaminant and hazardous materials. The objective is to neutralise the vessel in such a way that its dismantling in existing capability, ideally, would not create environmental problems or that in practice these factors would be substantially if not totally eliminated.

In practical terms, this would require the vessel to be stripped of environmentally hazardous materials such as those listed below:

- Asbestos
- Fuel oil from bunkers and lines
- Lead and TBT/TPT based paint systems
- Lubricating and hydraulic oils
- PVC, polystyrene, phenol foam and other combustible plastics
- CFCs from HVAC and refrigerant systems
- Solid wastes from settlement tanks
- Contaminated bilge water
- Residual cargo contents
- Ballast water and sediments

Additionally, the tanks, bunkers and pipelines of the vessel will need to be flushed and cleaned to remove residual traces of contaminants.

The result of a "neutralisation" process would be a "dead" ship without power systems. The vessel would need to be transported to the scrapping facility under tow or other independent powering. The costs of towing will impose a considerable expense and would have to be factored into the overall economics of the process. Furthermore, a towing operation itself, is a safety critical operation representing the potential of causing incidents that may have environmental consequences.

In view of the lack of physical containment at existing facilities and other poor environmental controls, the extent of pre-processing would need to include the removal of all surface paint coatings from the hull and other elements of the vessel. This would be a very extensive task.

However, if it was excluded or only partially undertaken during pre-processing, then non-compliant activities would continue at the scrapping location.

The stripping, de-toxification and cleaning process would need to be undertaken by a competent operator, potentially existing ship repair yards, for which there would be a cost. Given that there is little of a commercially profitable recycling nature in this work, this cost is unlikely to be offset by recycling revenues to the contractor.

The majority of existing scrapping capability is based on beaching the vessel, using the ship's own power to drive the vessel as far up the beach as possible to make the hull accessible and to reduce transfer distances for components. A dead ship would have no such power and it cannot be envisaged how the same objective could be easily and cheaply achieved by any other means.

Once at the final location, the physical dismantling process would be undertaken, presumably, along the same basis at it currently occurs. Whilst the non-compliance associated with hazardous substances would be avoided, the concerns regarding the health and safety of current working practices would continue. Some of those environmental non-compliance issues associated with the dismantling process itself and associated downstream recycling operations would still be present.

In summary the concept of pre-processing is seen to raise some major practical and economic issues:

- Cost of pre-processing work within OECD Europe;
- Cost of towage of dead vessel to final destination;
- Practical difficulties in beaching the vessels at final destination;
- Continued health and safety hazards to scrapping personnel;
- Continued environmental non-compliance of the dismantling process and downstream recycling practices.

In terms of economics, the cleansing operation costs are likely to be same or greater than those undertaken in a dedicated ship scrapping facility, the towage cost would be simply an additional cost. Taken together with the practical problems of beaching the vessel, it would seem that the economics of pre-processing are likely to be less advantageous than those of ship disposal within Europe. Additionally, little benefit would be achieved in terms of the dangerous and hazardous working conditions of the operators and in some part environmental non-compliance would continue in the downstream dismantling and recycling processes. This option, which would not require any major development of facilities as it could be undertaken at existing repair yards, has not been explored further.

8.2 Ship Dismantling Facility

To be environmentally acceptable and compliant, any new developments, whether brownfield or greenfield, specifically designed for the breaking of the world fleet surplus, both commercial and naval, must be configured and operated differently from existing ship scrapping facilities.

In essence this is introducing a new generation of facility, the second generation facility, which will be referred to as a ship dismantling facility rather than a ship scrapping or ship breaking yard. In the near term, it is likely that this process will still be fairly labour intensive, but that there will be a much higher degree of control over both the processes and outputs of the facility. Clearly, where automation is possible and cost effective, the technology will be incorporated into the design of such facilities to make them efficient in terms of layout, operation and disposal/recycling outputs. However, as always the cost balance between capital investment and productivity improvement will vary according to whether the facility is located in a low, medium or high cost economy.

The scope of this study does not support the detailed design of a facility and, additionally, much of the technology and application would be novel. The following sections describe the basic concept, functionality and operation of the envisaged facility.

The concept has been based upon volume throughput of ships for dismantling, taking into account the projected future volumes identified in chapter7.

8.2.1 Functionality

The above requirements are considered to be best met by adopting a well-planned and structured dismantling approach to ship breaking. Simplistically, ship dismantling will, in large part, be the inverse of the original ship building operation. Conceptually dismantling will involve:

- Removal, from the vessel whilst afloat, of consumables and loose components;
- Removal of the ship out of the water;
- Break up of the vessel into major sections that can be subsequently dismantled into smaller components;
- Careful removal of hazardous or polluting materials where necessary, e.g. asbestos, metallic compounds, residues;
- Collection and storage of recyclable raw materials, waste products and any re-usable components;
- Despatch of outputs to recycling, re-use and disposal centres or customers.

The range of vessel sizes, which need to be accommodated for breaking, is extensive, hence as with new building yards, facilities will need to be designed to suit a range of ship sizes. In particular the means of transfer of the vessel from sea to land is likely to differ according to size and anticipated throughput. For example, marine railways will be suitable for small vessels, ship lifts for vessels up to around 30,000 dwt and dry docks for larger vessels. However, in practice a single volume throughput facility needs to cater for all sizes of vessels and will therefore reflect the largest vessel sizes.

In terms of product mix, the distinction between ship types is considered to be less important for ship dismantling compared to shipbuilding. Although perhaps cruise ships, naval vessels and other non-cargo carrying vessels are likely to prove exceptions to the norm as a consequence of the greatly differing ratio of steel to outfit content prevailing and the wide variety of output materials.

Typically, a dismantling yard will comprise the following key functionality:

- Wet berths, used to moor vessels alongside upon arrival at the yard prior to the start of the dismantling activities allowing general preparations to be undertaken;
  - Clearing of all residual materials at a *cleaning/ waste reception station* (incl. clearance of e.g. any cargo ullage in tanks or holds, bunker and fuel tank, contents, all bilge and oily water, sewage tank contents, ballast water and sediments, etc.)
  - Vessel is made gas free and certified

- Ensure that ship is presented for dismantling in a clean and safe condition

- The primary dismantling facility, or facilities, which takes the ship out of the water, isolate it from the marine environment and allows the initial vessel breakdown into large blocks or sections.
- Large capacity cranes allowing these large sections to be removed from the primary dismantling facility.
- Workstations for secondary dismantling activities and sequential breakdown into component elements. Special enclosed workstations will be required to provide containment during the removal of hazardous and toxic materials.
- External storage areas which hold benign steelwork and materials between different stages of dismantling.
- Secure, and open, storage that holds fully processed equipment and materials ready for output from the facility for recycling, re-use or disposal.

Figure 8-1 shows a conceptual illustration of such a facility designed to accommodate larger vessel types.

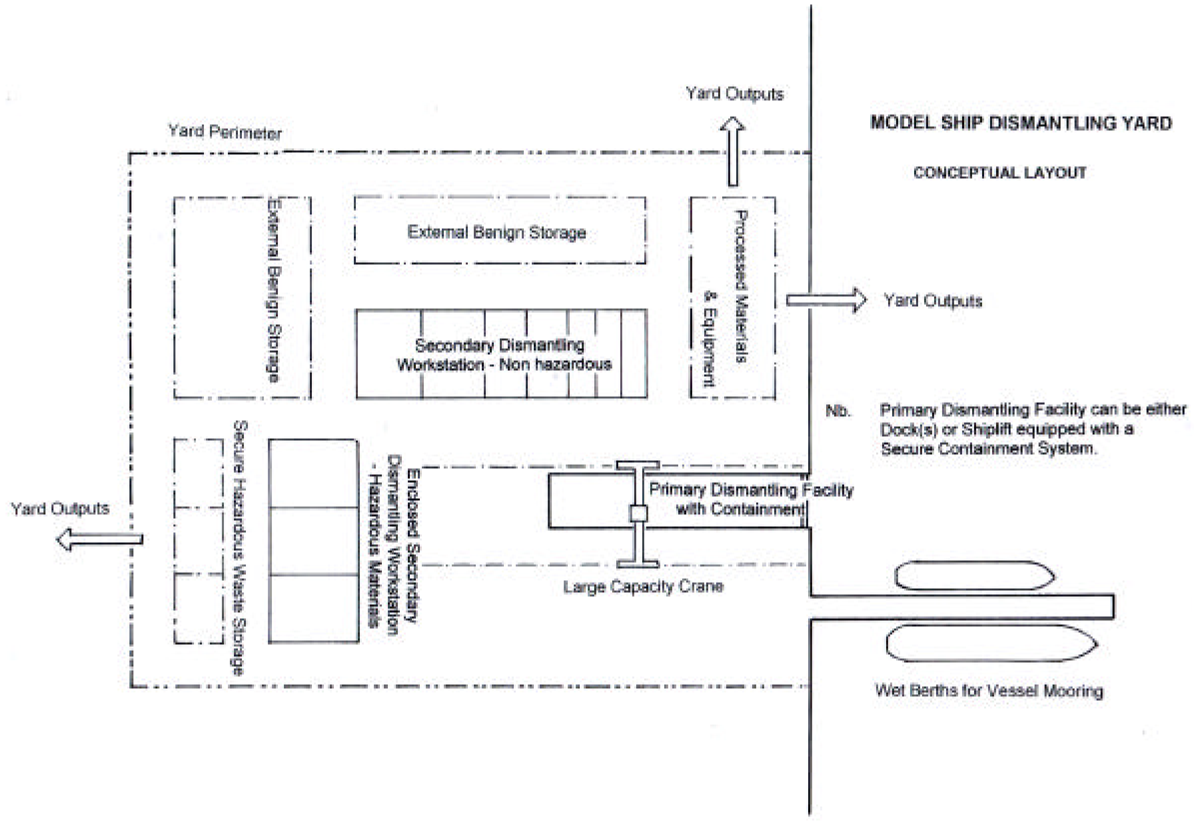


Figure 8-1 Model Ship Dismantling Yard – Conceptual Layout

The yard's primary dismantling facility will need to provide guaranteed containment of any unscheduled spills arising from the initial stages of the dismantling activities. This would effectively isolate the ship from the marine environment, particularly during the critical initial stages when the integrity of both hull and ship major systems are first breached.

The type of primary facility (marine railway, ship lift or dock) to be provided will be dependent upon a number of factors:

- The size range of ships to be accommodated.
- The product mix of ships to be processed.
- The prevailing site topography and ground conditions.
- The annual throughput of ships to be deconstructed.

Eventual layout adopted for any individual yard will also be largely dictated by these same factors.

The size distribution of the world fleet (chapter7) demonstrates that a docking capacity of 400,000 dwt. would be sufficient (in size) for almost the entire fleet, since only 0.1% (by no.) of the world fleet are above 400,000 dwt.

The primary facility will drive the complete operation. This will need to be provided with large capacity cranes (related to the ship size range to be accommodated) to maximise the throughput potential of the yard. All downstream facilities and activities will be sized and organised so as to minimise the possibility of creating bottlenecks within the dock, shiplift or marine railway elements of the operation.

All open work areas will be fully paved and all surface water drainage systems will be equipped with large capacity pollution traps to ensure that any solid or liquid contaminants which may be spilt cannot find their way into local waterways or permeate into the water table.

8.2.2 Operation

To our knowledge, no second generation ship dismantling facility yet exists. The principles outlined in the following section are based upon a novel synthesised dismantling methodology. The component elements of the synthesis, however, are based upon established production processes, handling methods and strategic approaches. Parallels can be found in current ship building, ship conversion and industrial dismantling operations.

The operations and facility descriptions are for a large scale, high throughput, ship dismantling activity specialising particularly in steel intensive ship types (dwt carriers). It is envisaged that a single facility with a single 400,000 dwt drydock would be able to handle the predicted annual throughput levels for either OECD or geographical Europe definitions.

In terms of preparations planning, it is envisaged that broad ship dismantling strategies will be developed for each of the common ship types dismantled, which clearly identifies special problem areas to be expected and the overall dismantling approach to be adopted. Individual details of particular vessels will then be required to plan a safe dismantling operation. It is likely that shipowners will be responsible for providing details on the material composition of their vessels (or for new tonnage, builders to provide inventory details on delivery) in the form of a ships “passport” (ref.: /33/).

Prior to commencement of the dismantling activities, the ship will be cleared of all residual materials at a cleaning/ waste reception station (Wet Berths for Vessel Mooring,Figure 8-1). The clearance will include, inter alia, any cargo ullage in tanks or holds, bunker and fuel tank contents, all bilge and oily water, sewage tank contents, ballast water and sediments, etc. The vessel will be fully gas freed and certified. Actions will ensure that the ship is presented for dismantling in a clean and safe condition.

Large diameter pipe work, such as tanker cargo pipe work, will also be cleared, cleaned and marked accordingly. Smaller diameter pipe work will be cleared; cleaned and marked only if convenient or necessary to do so at this stage, otherwise they will remain charged to be dealt with later.

Prior to the main steel dismantling process beginning, the ship will be examined and the sequence and nature of the work to be performed agreed upon and planned as a specific extension to the appropriate broad strategy. Preliminary outfit removal and/ or make-secure work in way of dismantling breaks will also be commenced at this time. As much outfit material as possible will be removed prior to transferring the ship to the primary facility. Access to the ship builder's original strategy documentation will be useful at this juncture.

The ship will then be transferred to the dock and associated dismantling facility, which is configured to maximise the efficiency of steel breakdown activities. The ship will be cut up into ring units of appropriate length to most closely match the capacity of the main dock crane and thereby minimise the actual work content within the dock.

Large blocks and units, complete with almost all remaining elements of outfit and machinery installation, etc. will be removed for subsequent dismantling or specialist decontamination elsewhere on site. Only where remaining outfit items cross a dismantling break will they be either severed or removed. Any charged and unmarked pipelines will be blocked on both sides of any necessary breaks to prevent significant spillage occurring.

Very large items, such as main propulsion machinery, auxiliary generators, etc. may need to be removed in the open sky condition, but wherever possible, outfit and machinery will be left complete within the enclosing steel unit.

Blocks and units removed from the ship are craned initially to areas of the yard adjacent to the dock and under cover of the main crane for limited further dismantling into large interim products approximating to two dimensional panels. These panels are then transported to other areas of the yard for subsequent breakdown into ever smaller pieces down to the desired size for most cost effective disposal. Hazardous activities such as the removal and bagging of asbestos insulation, removal of anti-fouling and lead based coatings, etc, are performed under cover to prevent the possibility of airborne dispersion across and beyond the yard boundaries.

A considered set of facility specific contingency plans and associated procedures will be developed to respond to any accidental release of hazardous or toxic wastes. Such plans will include all SHE aspects.

During subsequent dismantling activities, the unit size of breaking components is progressively reduced and organised into distinct lines, typically:

- Major outfit items – propellers, engines, generators, large electric motors, purifiers, anchors, chains, etc.
- Minor outfit items – small electric motors, starter units, fans, etc.
- Pipework systems – pumps, valves, steel and non-ferrous pipe and tubing, etc.
- Cabling - armoured, MICC, PVC insulated, etc.
- Timber and timber products
- Domestic, kitchen, sanitary fittings, etc.
- Miscellaneous - Ship wheels, compasses, bells, etc.
- Waste - benign materials with little or no resale or re-cycle value

- Toxic and hostile materials requiring licensed disposal
- Etc.

The yard will be primarily responsible for reducing the steel hull and steel accommodation component of ships into optimised scrap for recycling. Large, steel intensive items, such as slow speed marine diesel engines may also be reduced to optimised scrap.

It is probable that some elements of the technology required to allow the dismantling work to be undertaken in the manner described either does not presently exist or is inadequately developed to allow immediate adoption.

Environmentally responsible ship dismantling will be a new industry and, as such, will need time for all necessary operational and management tools to be properly developed.

8.2.3 Description of the Model Facility

The facility described in outline here is configured for the routine dismantling of large, steel intensive vessels which collectively display a high degree of conformity in their structural design configuration.

It is considered that the facility needs a minimum site area of 20 hectares offering an absolute minimum of 250 metre of water frontage adjacent to deep water access.

A 400 metre long and 15 metre wide finger jetty is provided to accept incoming vessels and where initial dismantling activities commence with the removal of as much outfit items and materials as possible prior to entering the dry dock. The jetty operates a 20 tonne capacity travelling jib crane to furnish the large number of smaller lifts envisaged at this stage of the dismantling operation. On the jetty is installed initial Cleaning/ Waste reception facilities for relevant cleaning operations (gas free, etc.) and waste categories (domestic waste, consumables, operational waste, cargo remains, etc, see 8.2.2). This will be equipped with pumps, venting arrangements, electrical supply, etc. as well as facilities for containment and transport.

The facility is concentrated around a single large dock capable of accommodating vessels of up to 400,000 dwt. The dock floor is provided with a secondary bund system to contain any leakage or accidental spills and to prevent these entering the dock de-watering and leakage stripping system. The dock is fully equipped with all electrical and mechanical services necessary for the effective deployment of the types and numbers of cutting and associated equipment employed to cut the ship into large ring units.

The dock is bounded along one side and across the dock head by hard-standing work areas where the ring units from the dock are reduced down to their constituent panels. The dock head area is used mainly for complex shaped steel work such as bow and stern sections as well as accommodation blocks. These areas are also provided with bunds to contain spills and prevent contamination of the adjacent ground. All surface water drainage is routed through separators and settlement tanks to reduce pollutants to acceptable levels. The hard-standings are provided with all necessary electrical and mechanical services to support production.

The combined dock and hard-standing areas are covered by a circa 500 tonne lift capacity large span portal crane which transfers the ring units from the dock ashore. Two 20 tonne jib cranes also service the hard-standing areas to perform the smaller, more frequent lifts, encountered during the subsequent dismantling activities.

A further large external hard-standing area is provided where the relatively large panels, output from the areas adjacent to the dock, are reduced down to the sizes which command the maximum scrap or re-use values. Materials handling activities in this area are predominantly undertaken with mobile cranes, a single unit of 50 tonne capacity and four 25 tonne machines.

All external areas are equipped with flood lighting to allow 24 hour working be undertaken.

A three bay workshop is also provided on site in which the piece small dismantling of steelwork, piping and equipment which is environmentally hostile or is valuable or easily damaged is undertaken. The building structure provides the primary enclosure to minimise the risk of any pollutants or contaminants escaping into the external biosphere. The workshop is equipped with a range of overhead cranes with capacities matched to the both the initial and final scale of the dismantled products. As with elsewhere on the site, the workshop is fully equipped with all necessary electrical and mechanical services to support the range of dismantling activities undertaken.

A stores building provides secure containment of hostile and valuable materials prior to their dispatch from site for reuse, recycling or disposal. Materials handling activities within the stores building is performed with fork lift trucks.

A number of support buildings are provided within the site boundaries, these comprising of the main administration and amenities block, a medical centre and a fire station. Traffic and personnel movements into and out of the site are controlled from a single gate-house. Car parking is provided in the area adjacent to the administration building.

All buildings and work areas are inter-connected by a comprehensive road network.

8.2.4 Production Equipment

The production equipment spend anticipated for the yard is concentrated in two particular areas, steel cutting and materials handling. These two activities will dominate the ship dismantling operation as defined.

For steel cutting high energy plasma processes are used for all large scale plate cutting activities wherever possible with secondary cutting undertaken by either conventional oxy/fuel torches or via more specialised processes such as oxygen arc or powder cutting. A high degree of process mechanisation is considered to be essential. Such mechanisation would need to be specially developed to suit ship dismantling activities.

For reducing the steel down to acceptably small pieces for reprocessing, a large proportion of cutting will be performed by large, heavy duty, mechanical shears mounted on the booms of tracked excavators. Such shear/excavator combinations are extensively used during the dismantling of large, land based, steel structures such as power stations.

Most of the movements of large panel type structures from the areas adjacent to the dock to subsequent breakdown external areas and in the workshops will be done with self elevating transporters similar to the types common in modern shipyards. A number of these vehicles of varying capacities will be required to meet the large number of load movements required. It is anticipated that these will operate independently of the main facility craneage by deploying stools from which to place and recover loads.

The mobile cranes, which service the final external steel cutting area, are all of the telescopic mast type, all terrain types able to operate mostly without the need to deploy their stabilisers.

Where the load or outreach demands the stabilisers be used, the hard standing is sufficiently strong and level to minimise the deployment time.

The compressed air demands for the complete facility are met by a set of three centrally located compressors installed within a dedicated compressor house.

8.3 Greenfield/ Brownfield Site Alternatives

8.3.1 Brownfield Site Development

In terms of looking at the availability of existing brownfield sites, one of the key issues is the availability of docking capability to allow the vessels to be taken out of the water for break-up within a contained environment. For all but the smallest vessels, this suggests an existing dry-docking or ship lift capability – floating docks do not provide the necessary containment and as a means of lifting to transfer from water to land, specific site conditions would need to be considered at each location. Ship lifts tend to be limited to vessels up to 35,000 dwt. For this reason, the consideration of brownfield facilities has been limited to dry docks.

Clearly within Europe there is existing dry-docking capability around which brownfield development(s) could be undertaken. Within Western European countries, much of this dry-dock capability is in current shipbuilding or repairing use and additionally the relatively high cost of labour in these economies, provides a poor base against which to develop such a capability.

On this basis, we have concentrated the consideration of brownfield development on the lower cost economy countries within Europe. Table 8-1 lists the main dry docks in these countries:

Table 8-1 Dry-docks – Eastern/Central Europe

Country	*Yard*	*Location*	*L x B x D*	*DWT*
Latvia	Tosmare (1)	Liepaja	225 x 35 x 9	20,000
	(2)		185 x 38 x 9	18,000
Bulgaria	Varna (1)	Varna	237x40 x 5.5	80,000
	(2)		190x23 x 4.5	30,000
	Odessos	Varna	243x 27 x 10	30,000
Romania	Constantza (1)	Constantza		200,000
	(2)		360x 48 x 10	160,000
	Daewoo MHI (1)	Mangalia	360 x 60 x 7	200,000
	(2)		300 x 48	160,000
	Galatz	Galatz		60,000
Poland	Radunia	Gdansk		40,000
	MMS (1)	Gdansk		60,000
	(2)	Gdansk		
	Gdynia	Gdynia	380 x 70 x 8	400,000
	Intermarine	Szczecin		30,000
Estonia	Loksa	Loksa		6,000
Ukraine	Sevastopolsky (1)	Sevastopol	170 x 20	
	(2)		150 x 20	
	(3)		280 x 35	80,000
	Chernomorsky Zavod	Nikolaev	150 x 37	4,500
	Kherson	Kherson	140 x 32	
			140 x 18	
	Okean	Nikolaev	350 x 56	235,000
	Zaliv	Kerch	350x 56 x 11	235,000

Note: The capacity of a number of these docks is based upon the leading dimensions provided
The remaining docking capability in these countries is floating docks.

It can be seen that only Poland and Ukraine have significant sized docks that could accommodate the majority of cargo carrying ships in the world fleet. The dock in Poland is in current shipbuilding use and additionally, the development of the Polish economy has increased labour costs. Shipyard activity in the Ukraine is generally fairly low at the present time, with significant surplus or mothballed capacity. However, the financial climate is quite hard and the situation regarding social and environmental compliance is uncertain due to the limited inward investment and development. The largest docks in Romania can accommodate vessels up to approximately 200,000 dwt. However, these are located in shipyards that are currently active in both shipbuilding and repair.

The technology described in the previous section is based upon maximum throughput of vessels within a single facility. Utilising this approach the anticipated volumes of ships for dismantling can be handled within a single dock operation facility. Such a dock however would therefore need to accommodate the largest vessels.

The identified Eastern European docks capability comprises mainly smaller dry docks for vessels up to panamax size. Larger facilities are located at the following locations:

- Constantza in Romania for vessels up to 200,000 dwt
- Mangalia in Romania for vessels up to 200,000 dwt
- Okean in Ukraine for vessels up to 235,000 dwt
- Zaliv in Ukraine for vessels up to 235,000 dwt
- Gdynia in Poland for vessels up to 400,000 dwt

The largest of these docks at 400,000 dwt would be sufficient (in size) for almost the entire world ship dismantling workload, while the smaller facilities at 200,000 – 235,000 dwt would only be sufficient in size for around 80% of the dismantling workload.

Additionally, whilst there is under-utilisation of shipyard capacity within the Eastern European countries, most of these dry-docks currently have some shipbuilding or ship repair activity going on and therefore the availability of docking capability around which to develop a brownfield site would be proportionately reduced. Specifically the largest of these docks, at Gdynia in Poland, is part of a highly active shipbuilding facility.

8.3.2 Greenfield Site Development

As always with a greenfield site development, the factors influencing location are more general. In this instance they focus down on the following:

- Sea access for arriving vessels – suitable for a docking facility
- Availability of low cost labour
- Availability of suitable energy supplies
- Supporting logistics infrastructure
- Political stability
- Suitable political and legislative context to support social and environmental requirements

Taking into account EU membership, the timetable for enlargement and the requirement for low labour costs, the following have been identified as the possibilities:

- Balkan States
- Bulgaria
- Greece
- Poland
- Romania
- Slovenia
- Turkey

Whilst the required capacity is significant, there is clearly plenty of scope for development of purpose developed scrapping facility on either a single or multiple site locations.

In terms of the relative economies of operating in these countries, this will primarily be a function of unit labour costs and productivity, in conjunction with the energy costs and the cost of facilities development. It is not possible to be prescriptive about this.

However, it should be noted that greenfield developments are likely to face quite strong resistance. The Australian project (ref. chapter 5.2.4) has already had its preferred site rejected and site selection has caused the most problems for the consortium so far.

9 ECONOMIC AND COMMERCIAL FACTORS

In considering the overall economics of an environmentally compliant ship disposal facility, we have looked to calculate a ship end-of-life value per steelweight tonne to compare with the current market values of vessels sold for scrapping.

To do this we have used a simple economic model:

Ship end-of-life value = annual net profit/loss of dismantling ÷ steel workload in tonnes

The annual net profit or loss of dismantling operations has been calculated as the projected net revenue streams of the operation from the resale of waste materials less the costs of dismantling operations. The dismantling costs comprise three main elements:

- operational costs of dismantling process.
- labour cost.
- facility costs.

9.1 Revenue Streams

The revenue streams of the operation have been determined through identifying those material output streams for which a resale value is anticipated. The annual volumes of material have been estimated based on the predicted scrapping workloads in section7.2. Unit resale values have been assumed based on each such revenue stream.

Values of recycling materials are generally highly volatile as they reflect demand and supply situations in the commodity markets. For the basis of this study however, values have been assessed taking into account the current market prices and trends.

There are however other waste material streams that it is anticipated will represent disposal costs for the operation. The costs of these have to be offset against the revenue streams to calculate the net revenue of the operation. Unit disposal costs have been assumed for each waste disposal stream. These are identified in the table below. Such disposal costs are also likely to be subject to market variations and in particular to changes in the cost and availability of landfill and the regulation and licensing of specialist disposal contractors.

The net revenue streams from waste materials have been estimated for the scrapping workloads associated with both OECD European flagged vessels and geographical Europe flagged vessels (see Table 9-1).

Table 9-1 Revenue of waste streams estimated for Europe

Waste Stream	Revenue or Cost	Value $ / tonne	Revenue US $ million OECD Europe	Revenue US $ million Geog. Europe
Steel	Revenue	80	68.8	118.4
Copper	Revenue	1780	0.2	0.4
Zinc	Revenue	1030	0.4	0.6
Special Bronze	Revenue	1200	0.4	0.7
Machinery	Revenue	50	8.1	13.8
Electrical/Electronic Equipment	Cost	-70	-2.0	-3.4
Joinery – related products	Neutral	0	0.0	0.0
Minerals	Cost	-30	-0.2	-0.3
Plastics	Cost	-30	-0.2	-0.3
Liquids	Neutral	0	0.0	0.0
Chemicals and gases	Cost	-70	0.0	0.0
Other miscellaneous	Cost	-70	-0.8	-1.4
Net Revenue			**74.3**	**128.5**

9.2 Cost Base

9.2.1 Dismantling Operational Labour Costs

The dismantling operational costs include the labour costs of the direct and indirect workforce, including management and administration personnel. As with all shipyard operations and other labour intensive processes, the labour costs will be the dominant cost driver in these operations.

Direct manning levels for the steelwork dismantling process have been calculated using a variety of technologies, based upon the steel cutting and handling activities necessary to break empty steel ships structure into 1.5 x 0.5 x 0.5 metre elements. This size of final component is driven by current steel scrap standards. The results of these calculations have given steel productivities between 1.2 and 3.5 manhours/ tonne. For our calculations we have used a mid-range figure of 2.3 manhours/ tonne.

The manning levels required for the dismantling operations for outfit and machinery areas have been calculated on a pro-rata basis, reflecting the overall composition of steel, machinery and outfit content for ship newbuilding. The premise underpinning this assumption is that the process of dismantling is the reverse of ship construction and that steel, outfit and machinery components are largely being dismantled back to original components or similar component size (in the case of steel). The level of complexity and alignment elements are of course not applicable in dismantling, however this is a common factor. Labour associated with painting, commissioning and testing can be ignored in calculating the ratios, as there is no parallel dismantling operation. A ratio of 60/40% has been assumed based on the labour composition of traditional full service yards without sub-contracting.

The level of management and administration personnel has been based upon appropriate industry standards for operations with similar manning levels. Significant levels of technical and design personnel are not envisaged.

The following table presents the calculations for operational manning levels for the workload range previously estimated.

Table 9-2 Manning levels

	OECD Europe	**Geographical Europe**
Steelweight throughp. approx (tonnes)	860,000	1,480,000
Steelwork productivity	2.3 mhrs/tonne	2.3 mhrs/tonne
Steelwork manning (60% direct)	1,130	1,945
Outfit manning (40% direct)	755	1,295
Total direct manning	1,885	3,240
Indirect manning	500	700
Total	**2,385**	**3,940**

Based on the above calculations, yard manning levels have been rounded up to 2,400 and 4,000 respectively for the purpose of estimating labour costs. The following table shows the labour costs of the operation for a range of employment cost rates.

Table 9-3 Operational labour costs

	OECD Europe US$ million	**Geographical Europe US$ million**
Employment cost $2.5/hr	12.2	20.3
Employment cost $5.0/hr	24.3	40.6
Employment cost $10.0/hr	48.7	81.1
Employment cost $20.0/hr	97.3	162.2

9.2.2 Other Operational Costs

Other operational costs comprise mainly the non-labour overhead costs for both production and administrative elements. The production labour costs will relate primarily to the use of consumables in the cutting and dismantling process, e.g. energy, gases, etc. These can be expected to be significantly higher than for traditional shipyard operation in view of the high level of steel cutting. The extent to which mechanical cutting is adopted, as opposed to thermal cutting processes for secondary dismantling, will significantly influence the consumable costs. Other overhead non-labour costs are estimated based upon typical shipyard costs.

For the purpose of the analysis, the following values have been used for other operational costs:

Table 9-4 Other operational costs

	OECD Europe US$ million	**Geographical Europe US$ million**
Production overhead	5.4	9.4
Other overhead	2.0	3.0
Total	**7.4**	**12.4**

9.2.3 Facility Costs

The capital costs of developing the ship dismantling facility have been based around the provision of a single facility, which has the capability of handling the envisaged annual throughput. The key functionality of the facility is described in Section 8.2, and has been categorised as follows for costing purposes:

- **Finger jetty** - jetty, crane, bollards and fendering
- **Dock and dockside area** - dry dock, dock cranes, hard standing and drainage
- **Workshops** - buildings, services, and internal cranage
- **Ext. dismantling area** - open areas with drainage and contained settlement tank system
- **Plant and machinery** - mob. cranes, transporters, shears/plasma equip, compactors
- **Miscellaneous buildings** - administration buildings etc

Table 9-5 Facility development costs

Item	Capital Cost US $ million	Working Life Years	Depreciation US $ million
Dry dock & dockside areas	66.3	40	1.66
Finger jetty	9.0	40	0.22
Workshops	8.5	40	0.21
Open dismantling area	1.6	40	0.04
Plant and machinery	8.4	15	0.56
Misc. buildings	2.0	40	0.05
Total	**95.8**		**2.74**

It can be seen therefore that the capital cost of the facility is estimated to be approximately US$100 million. Based upon the useful working life of these assets, this has been converted into an annual depreciation charge of US $ 2.74 million.

9.3 Economics of Ship Dismantling Facility

It can be seen that the main variable of the shipyard costs is that of labour costs and the overall economics of the process will reflect the differing costs of labour in different countries. The following table demonstrates the revenue cost balance for four different labour rates. In this simplified calculation no financing costs have been included for the cost of capital investment in developing the facility.

Table 9-6 Projected annual cost and revenue levels (US $ million)

	OECD Europe				Geographical Europe			
	$2.5/hr	**$5/hr**	**$10/hr**	**$20/hr**	**$2.5/hr**	**$5/hr**	**$10/hr**	**$20/hr**
Labour	12.2	24.3	48.7	97.3	20.3	40.6	81.1	162.2
Other	7.4	7.4	7.4	7.4	12.4	12.4	12.4	12.4
Depreciation	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Total Cost	-22.3	-34.4	-58.8	-107.4	-35.4	-55.7	-96.2	-177.3
Net Revenue	74.3	74.3	74.3	74.3	128.5	128.5	128.5	128.5
Balance	**52**	**39.9**	**15.5**	**-33.1**	**93.1**	**72.8**	**32.3**	**-48.8**

As the employment costs rise, the costs of dismantling start to exceed the net revenues of the operation, indicating that there would be a net cost to ship dismantling in higher labour cost countries. In the above table the move from positive to negative balance occurs between $10/hour and $20/hour. A *simplistic* calculation of the break-even employment costs (i.e. where net revenue are equal to total cost) indicates $13/ hour for the lower volume OECD Europe scenario and $14/hour for the higher volume Geographical Europe scenario.

9.4 Ship End-of-Life Value

The end of life value for ships based upon the above economic analysis has been calculated per tonne of steelweight to allow comparison with current scrapping prices being achieved for vessels sold for scrap.

Based upon the figures presented in Table 9-6 in Section 9.3, the following end-of-life values per steelweight tonne have been calculated:

Table 9-7 Ship end-of-life value, denoted in US $ per steelweight tonne

	OECD Europe US$/ steelweight tonne	**Geographical Europe US$/ steelweight tonne**
Employment cost $2.5/hr	60	63
Employment cost $5.0/hr	46	49
Employment cost $10.0/hr	18	22
Employment cost $20.0/hr	-38	-33

10 REFERENCES

/1/ " A technological review of the possible methods of decommissioning and disposing of offshore oil and gas installations". Contract No B4-3040/96/000259/MAR/D1. John Brown Engineers & Constructors B.V. for The European Commission DG XI and DG XVII, December 1996.

/2/ US naval Vessel Register (official list of US Navy ships, past and present) http://www.nvr.navy.mil/quick/inactive.htm

/3/ The world Navies Today, by Andrew Toppan. http://www.hazegray.org/ or http://www.hazegray.org/worldnav/usa/decom.htm

/4/ Transport statistics for the EU Member States, INLAND WATERWAYS, European Communities, 1995-2000: http://europa.eu.int/en/comm/dg07/tif/3_means_of_transport/ch3_iww_tran_eqpt.htm

/5/ Hans Strelow: Database of inland cargo vessels, EU 2000, - personal communication

/6/ Institution of Chemical Engineers (IChemE),environmental conference, Environment97: http://www.environment97.org/text/reception/r/keypapers/papers/s11.htm

/7/ UNEP – Offshore Oil and Gas ENVIRONMENT FORUM: "International Expert Meeting on Environmental Practices in Offshore Oil and Gas Activities", Noordwijk, the Netherlands, 1997:

http://www.natural-resources.org/offshore/emissions/decomm/index.htm

/8/ ENCYCLOPÆDIA BRITANNICA, Approximate Strengths of Selected Regular Armed Forces of the World, 1998: http://www.britannica.com/bcom/eb/article/single_table/0,5716,136725,00.html

/9/ T. Nilsen, I. Kudrik and A. Nikitin, 1996, *"The Russian Northern Fleet Nuclear-powered vessels"*, Bellona report: http://www.bellona.no/imaker?id=11091&sub=1#O0

/10/ Lloyd's ship demolition database for the year 1999 (generated for DNV, 2000)

/11/ Lloyd's Register of Shipping, *"World Fleet Statistics, 1998"*, London 1999. (http://www.lr.org/information/publications)

/12/ Lloyd's Register of Shipping, *"World Fleet Statistics, 1999"*, London 2000. (http://www.lr.org/information/publications)

/13/ Warships on the web, Royal Navy Encyclopedia, by Andrew Cashmore http://www.warships.co.uk/

/14/ Defence Reutilization and Marketing Service (DRMS), scrapping contracts completed since 1993. http://www.drms.dla.mil/marketing/ship.pdf

/15/ Lloyd's Register of Shipping: "*World Casualty Statistics, 1998*".

/16/ Organisation for Economic Co-operation and Development (OECD) 1997, Economy Research Centre, "What Markets are there for Transport by Inland Waterways?"

/17/ ENCYCLOPÆDIA BRITANNICA, *Canals and inland waterways* http://www.britannica.com/bcom/eb/article/9/0,5716,138639+2+117291,00.html

/18/ Drewry Shipping Consultants: "*Ship Scrapping – Locations, Activity, Price Trends and Problems. Briefing Report.*" October 1996. + recent data on ship scrapping by location (personal communication). October 1998.

/19/ DNV Report No. 99-3065: "Decommissioning of Ships - Environmental Protection and Ship Demolition Practices", 1999.

/20/ DNV Report No. 2000-3158: "Ship Breaking Practices/ On Site Assessment, Bangladesh – Chittagong", May 2000.

/21/ Lloyd's Register of Shipping: "*World Fleet Statistics, 1994*", London 1995. (http://www.lr.org/information/publications)

/22/ Lloyd's Register of Shipping: "*World Fleet Statistics, 1996*", London 1997. (http://www.lr.org/information/publications)

/23/ Internal DNV Memo based upon Fearnley/Lloyd's/DNV data

/24/ EPA PCB studie: http://www.epa.gov

/25/ DNV Report No. 98-4029: "Ekofisk 2/4 Q, 2/4 FTP, 2/4 R, 2/4 P, 2/4 T, 2/4 H, 2/4 A, 2/4B and Ekofisk I Pipelines. Material Inventory.", Phillips Petroleum Company, 1999

/26/ DNV Report No. 98-4024: "Asbestos survey on Frigg. QP, TP1, TCP2 and DP2.", Elf Petroleum Norge AS

/27/ DNV Report No. 97-3328: "Material Inventory Dossier. Heimdal Platform.", Elf Petroleum Norge AS

/28/ US EPA: "A Guide for Ship Scrappers – Tips for Regulatory Compliance", EPA 315-B-00-001, Summer 2000.

/29/ The EMBLA Homepage: http://projects.dnv.com/embla

/30/ The Chapman & Hall Encyclopedia of Environmental Science: "Chlorofluorocarbons (CFCs)", pp.78-80, Kluwer Academic, Boston, MA, 1999 or http://www.cmdl.noaa.gov/noah/publictn/elkins/cfcs.html

/31/ DNV Report No. 97-3564: "Maureen Alpha Decommissioning Environmental Effects – Acceptability Criteria's", Phillips Petroleum Company UK Ltd., Rev. 01. 1997

/32/ Waldock, M. J.: "Organometallic compounds in the aquatic environment", Handbook of Ecotoxicology, Vol. 2, 1994 (ed. P. Calow), pp. 106-129

/33/ DNV Report No. 2000-3160: "Decommissioning of Ships – Environmental Standards", Ship Inventory Dossier-Environment (SIDE), July 2000

/34/ Bjarte Bøe: “Opphugging av tankskip – Scrapping”, Skriftlig utredning ved Handelshøyskolen i Bergen, 1983

/35/ Raouf Kattan, -personal communication

/36/ Bertram & Wobig: “Simple empirical formulae to estimate main form parameter of ships”, *Schiff+Hafen*, Vol. 11, 1999, pp118-121

/37/ Schneekluth & Bertram: “Ship design for efficiency and economy”, Butterworth-Heinemann, Second edition, 1998

/38/ SFT: “PCB in building materials” (Norwegian), SFT Report No. 98:09, 1998

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APPENDIX

A
DECOMMISSIONING VOLUME - SUPPORT

Figure 10-1 and Figure 10-2 illustrate the world fleet distribution by type (cargo carrying vessels/ other vessels), number and tonnage (GT) over the period from 1994 to 1998. Nationality adherence distinguishes the OECD flag state registry fleet from the world fleet. The reason for presenting the growth of the world fleet in this way rests upon the ban amendment of the Basel Convention prohibiting the export of waste from OECD member states to non-OECD member states.

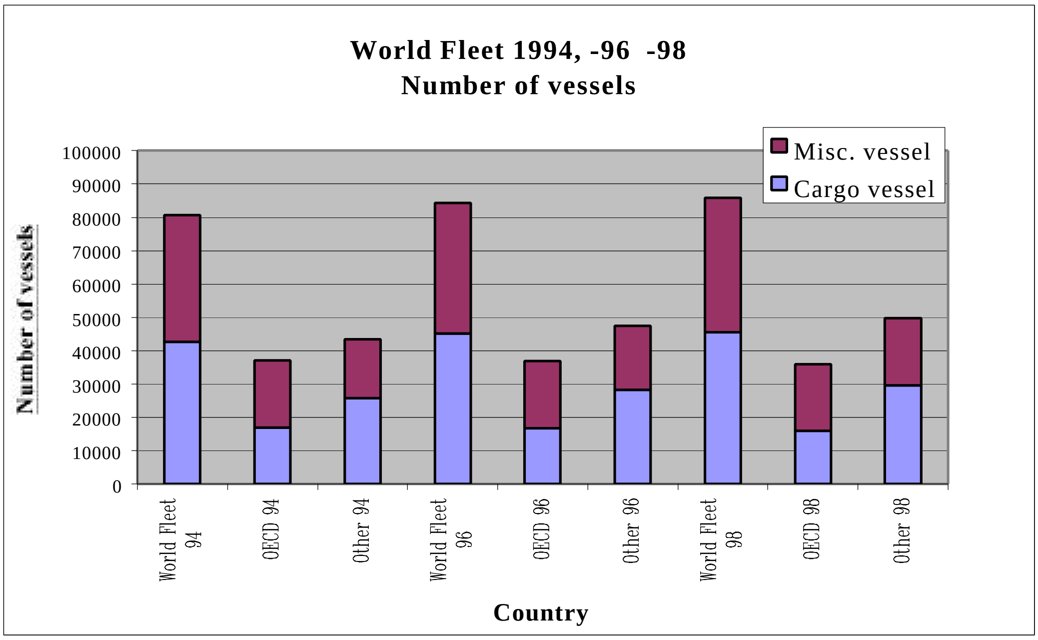

Figure 10-1 World fleet distribution by numbers

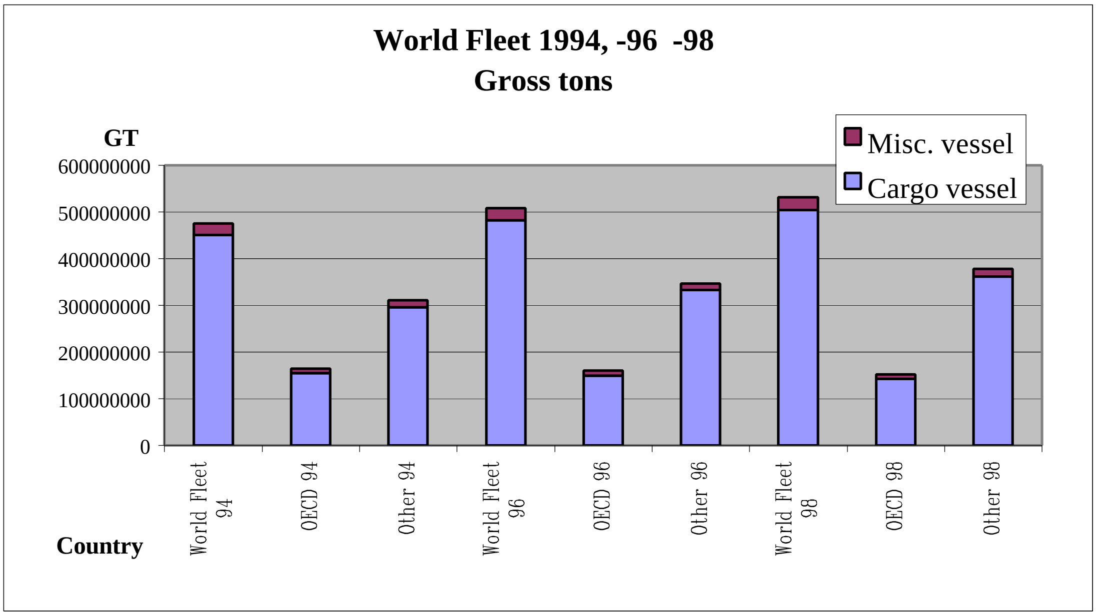

Figure 10-2 World fleet distribution by tonnage

Figure 10-3 shows that all OECD countries have experienced a reduction of volume (GT) with the exemption of Norway. Furthermore, the trend within the OECD is that of a decreasing number of vessels with the exemption of Norway, Korea, The Netherlands and USA.

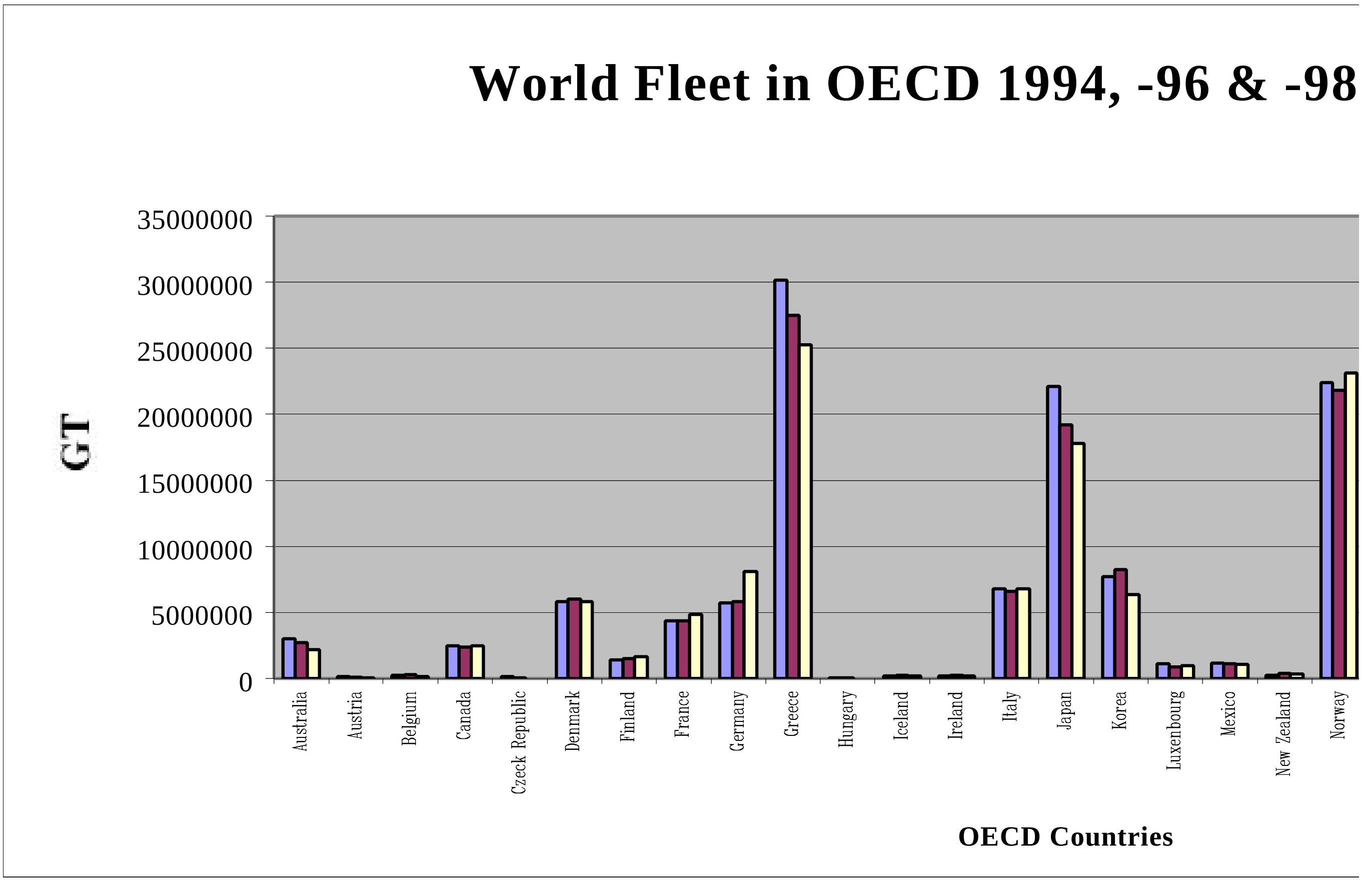

Figure 10-3 World fleet contributions from OECD countries (ref.: /11/21/22/**)**

Scrapping forecast – world fleet of cargo carrying vessels (2000-2025)

The calculated fraction in %, is based on the actual number of vessels and Dwt for each time period (Table 6 in Lloyd's statistics) divided by respectively the total number of vessel (45 576) and Dwt ($765.8 \cdot 10^6$).

The calculated fraction in %, is based on the actual number of vessels and Dwt for each time period (Table 6 in Lloyd's statistics) divided by respectively the total number of vessel and Dwt of vessels greater (or equal) than 10,000 Dwt.

Table 10-1 CARGO CARRING SHIPS – DEADWEIGHT AND AGE PROFILE IN %, 1999

Dwt category	% No.	% Dwt	Age	0-4		5-9		10-14		15-19		20-24		25+	
				% No.	% Dwt	% No.	% Dwt	% No.	% Dwt	% No.	% Dwt	% No.	% Dwt	% No.	% Dwt
4999 or less	58.3	5.2	21	5.00	0.52	7.85	0.73	7.35	0.60	8.00	0.80	8.58	0.86	21.48	1.71
5000-9999	11.6	4.8	16	2.06	0.87	1.68	0.69	1.45	0.61	2.16	0.89	2.04	0.86	2.21	0.88
10000-14999	4.5	3.3	16	0.83	0.59	0.53	0.38	0.50	0.38	0.81	0.60	1.03	0.76	0.82	0.61
15000-19999	4.1	4.2	17	0.55	0.57	0.29	0.30	0.45	0.46	0.85	0.88	1.40	1.41	0.57	0.56
20000-24999	3.1	4.1	15	0.72	0.97	0.36	0.47	0.26	0.35	0.56	0.75	0.78	1.05	0.40	0.52
25000-29999	3.0	4.9	17	0.48	0.79	0.25	0.42	0.40	0.66	0.61	1.00	0.67	1.09	0.55	0.90
30000-34999	1.9	3.7	17	0.34	0.65	0.10	0.18	0.20	0.38	0.44	0.85	0.54	1.03	0.30	0.58
35000-39999	1.9	4.3	16	0.20	0.44	0.14	0.31	0.36	0.82	0.62	1.38	0.44	0.98	0.16	0.36
40000-44999	1.8	4.6	12	0.36	0.92	0.36	0.90	0.51	1.28	0.35	0.88	0.18	0.44	0.06	0.14
45000-49999	1.7	4.6	7	0.84	2.33	0.30	0.85	0.24	0.65	0.17	0.46	0.07	0.20	0.05	0.15
50000-59999	0.9	2.8	14	0.15	0.47	0.13	0.42	0.13	0.41	0.21	0.67	0.18	0.59	0.08	0.27
60000-69999	1.9	7.3	13	0.33	1.30	0.31	1.23	0.31	1.21	0.64	2.44	0.26	0.99	0.05	0.18
70000-79999	1.1	4.9	8	0.61	2.64	0.18	0.77	0.05	0.24	0.14	0.63	0.09	0.39	0.05	0.20
80000-89999	0.6	3.1	15	0.10	0.49	0.04	0.22	0.12	0.59	0.18	0.89	0.15	0.76	0.03	0.15
90000-99999	0.5	2.7	10	0.08	0.46	0.22	1.24	0.07	0.40	0.04	0.21	0.06	0.34	0.02	0.08
100000-124999	0.5	3.6	10	0.23	1.44	0.08	0.53	0.05	0.30	0.02	0.16	0.13	0.90	0.04	0.26
125000-149999	0.8	6.3	13	0.12	1.00	0.23	1.93	0.08	0.69	0.15	1.25	0.16	1.25	0.03	0.21
150000-174999	0.6	6.0	7	0.32	3.06	0.17	1.60	0.07	0.62	0.02	0.21	0.04	0.41	0.01	0.06
175000-199999	0.1	1.3	13	0.02	0.21	0.01	0.09	0.05	0.60	0.02	0.26	0.01	0.14	0.00	0.02
200000-224999	0.1	0.9	11	0.01	0.11	0.02	0.24	0.03	0.32	0.01	0.17	0.00	0.03	0.00	0.00
225000-249999	0.1	1.7	16	0.00	0.03	0.02	0.28	0.04	0.59	0.00	0.00	0.05	0.64	0.01	0.15
250000-274999	0.3	5.4	15	0.04	0.57	0.09	1.44	0.05	0.76	0.01	0.14	0.11	1.79	0.04	0.69
275000-299999	0.3	4.5	9	0.09	1.49	0.11	1.81	0.01	0.18	0.01	0.11	0.03	0.58	0.02	0.29
300000-349999	0.2	3.6	7	0.10	1.85	0.04	0.74	0.01	0.24	0.00	0.08	0.03	0.58	0.01	0.12
350000-399999	0.0	0.8	22	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.09	0.03	0.66	0.00	0.05
400000 and over	0.1	1.4	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	1.43	0.00	0.00
Sum															
No/ Dwt	46002	8.E+08	0	6243	2.E+08	6211	1.E+08	5885	1.E+08	7375	1.E+08	7876	2.E+08	12412	7.E+07

Table 10-2 Scrapping forecast distribution in %.

Dwt category	% No.	% Dwt	Age	2026-2022		2021-2017		2016-2012		2011-2007		2006-2002		<2002	
				% No.	% Dwt	% No.	% Dwt	% No.	% Dwt	% No.	% Dwt	% No.	% Dwt	% No.	% Dwt
10000-14999	15.0	3.7	16	2.76	0.66	1.74	0.42	1.66	0.42	2.68	0.66	3.40	0.85	2.73	0.68
15000-19999	13.7	4.6	17	1.84	0.63	0.97	0.33	1.49	0.51	2.83	0.97	4.65	1.57	1.89	0.62
20000-24999	10.2	4.6	15	2.38	1.08	1.19	0.52	0.87	0.39	1.85	0.83	2.59	1.16	1.31	0.58
25000-29999	9.8	5.4	17	1.59	0.88	0.83	0.46	1.33	0.73	2.03	1.11	2.23	1.22	1.84	1.00
30000-34999	6.4	4.1	17	1.13	0.73	0.32	0.20	0.66	0.43	1.47	0.94	1.78	1.14	1.01	0.65
35000-39999	6.4	4.8	16	0.66	0.49	0.47	0.35	1.20	0.91	2.06	1.54	1.46	1.09	0.53	0.40
40000-44999	6.0	5.1	12	1.20	1.02	1.18	1.00	1.70	1.42	1.17	0.98	0.58	0.49	0.19	0.16
45000-49999	5.5	5.1	7	2.79	2.58	1.01	0.94	0.79	0.72	0.55	0.51	0.23	0.22	0.17	0.16
50000-59999	2.9	3.1	14	0.49	0.53	0.43	0.47	0.43	0.46	0.68	0.75	0.61	0.65	0.28	0.30
60000-69999	6.3	8.2	13	1.10	1.45	1.03	1.37	1.02	1.34	2.13	2.71	0.87	1.10	0.15	0.20
70000-79999	3.7	5.4	8	2.02	2.93	0.60	0.86	0.18	0.27	0.48	0.70	0.30	0.43	0.15	0.22
80000-89999	2.0	3.4	15	0.32	0.54	0.14	0.24	0.39	0.66	0.58	0.99	0.50	0.84	0.10	0.17
90000-99999	1.6	3.0	10	0.27	0.51	0.72	1.37	0.24	0.45	0.12	0.23	0.20	0.38	0.05	0.09
100000-124999	1.8	4.0	10	0.75	1.60	0.27	0.59	0.15	0.33	0.08	0.17	0.43	1.00	0.12	0.29
125000-149999	2.5	7.0	13	0.39	1.11	0.75	2.15	0.27	0.77	0.51	1.39	0.52	1.38	0.09	0.23
150000-174999	2.1	6.6	7	1.05	3.40	0.57	1.77	0.22	0.69	0.07	0.23	0.14	0.46	0.02	0.07
175000-199999	0.4	1.5	13	0.06	0.23	0.03	0.10	0.18	0.67	0.08	0.29	0.04	0.16	0.01	0.03
200000-224999	0.2	1.0	11	0.03	0.12	0.06	0.27	0.09	0.36	0.04	0.18	0.01	0.03	0.00	0.00
225000-249999	0.4	1.9	16	0.01	0.03	0.06	0.31	0.14	0.65	0.00	0.00	0.15	0.71	0.04	0.17
250000-274999	1.1	6.0	15	0.12	0.64	0.31	1.60	0.17	0.85	0.03	0.15	0.37	1.99	0.14	0.77
275000-299999	0.9	5.0	9	0.29	1.66	0.35	2.01	0.04	0.20	0.02	0.12	0.12	0.64	0.06	0.32
300000-349999	0.7	4.0	7	0.34	2.05	0.14	0.83	0.04	0.26	0.01	0.09	0.10	0.64	0.02	0.14
350000-399999	0.1	0.9	22	0.00	0.00	0.00	0.00	0.01	0.05	0.01	0.10	0.10	0.73	0.01	0.05
400000 and over	0.2	1.6	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	1.59	0.00	0.00
Sum %	100	100		21.6	24.9	13.2	18.2	13.3	13.5	19.5	15.7	21.6	20.5	10.9	7.3
Yearly average No/ Dwt*				598.8	34.8	365.8	25.5	367.6	19.0	540.8	21.9	598.0	28.7	**757.0**	**25.5**

* Based on an average in each time period

Table 10-3 Distribution of vessels scrapped by type;

Distribution, vessels above 10,000 DWT:

Ship Type	Tanker	Bulker	Dry cargo	Combos	Gas
Distribution by no.	26%	30%	40%	3%	1%
Distribution by DWT	51%	31%	10%	8%	0
GRT relation to DWT					
Average size (DWT)	120.000	52.000	13.000	130.000	-

Distribution, vessels below 10,000 DWT:

Ship Type	Tanker	Bulker	Dry cargo*
Distribution by no.	10%	25%	65%
Distribution by DWT	20%	26%	54%

* Including all other vessels other than bulk and tank.

The relationships between DWT scrapped and the representing GRT have been estimated for the two size categories respectively, and have been found to:

Vessels above 10,000 DWT: DWT/ GRT = 1.729

Vessels below 10,000 DWT: DWT/ GRT = 0.999

The World Navy Fleet

Table 10-4 Nato fleet (ref.: /8/).

Country	Submarines		Aircraft Carriers/Cruisers	Destroyers/ Frigates
	Nuclear	Diesel		
Belgium	--	--	--	3
Canada	--	3	--	16
Denmark	--	5	--	3
France	10	2	2	39
Germany	--	14	--	15
Greece	--	7	--	16
Italy	--	8	2	28
Netherlands, The	--	4	--	16
Norway	--	12	--	4
Portugal	--	3	--	10
Spain	--	8	1	17
Turkey	--	16	--	21
United Kingdom	15	--	3	35
United States	84	--	31	97
Sum	109	82	39	320

Table 10-5 Non-Nato-Europa fleet (ref.: /8/).

Country	Submarines		Aircraft Carriers/Cruisers	Destroyers/ Frigates
	Nuclear	Diesel		
Albania	--	1	--	--
Azerbaijan	--	--	--	2
Bulgaria	--	2	--	1
Croatia	--	1	--	--
Poland	--	3	--	2
Romania	--	1	--	7
Sweden	--	10	--	--
Ukraine	--	4	--	9
Yugoslavia	--	4	--	4
Russia	72	26	18	26
Sum	72	52	18	51

Table 10-6 SOUTH AND CENTRAL ASIA; EAST ASIA AND OCEANIA (ref.: /8/).

Country	Submarines		Aircraft Carriers/Cruisers	Destroyers/ Frigates
	Nuclear	Diesel		
Australia	--	4	--	11
Bangladesh	--	--	--	4
China	6	57	--	53
India	--	19	1	24
Indonesia	--	2	--	17
Japan	--	16	--	57
Korea, North	--	26	--	3
Korea, South	--	14	--	34
Malaysia	--	--	--	6
Pakistan	--	9	--	10
Philippines	--	--	--	1
Singapore	--	1	--	--
Taiwan	--	4	--	36
Thailand	--	--	1	14
Vietnam	--	2	--	7
Sum	6	154	2	277

Table 10-7 MIDDLE EAST AND NORTH AFRICA; SUB-SAHARAN AFRICA; LATIN AMERICA (ref.: /8/).

Country	Submarines		Aircraft Carriers/Cruisers	Destroyers/ Frigates
	Nuclear	Diesel		
Algeria	--	2	--	3
Egypt	--	4	--	9
Iran	--	3	--	3
Iraq	--	--	--	2
Israel	--	3	--	--
Libya	--	2	--	3
Morocco	--	--	--	1
Saudi Arabia	--	--	--	8
Syria	--	3	--	2
United Arab Emirates	--	--	--	2
Eritrea	--	--	--	1
Nigeria	--	--	--	1
South Africa	--	3	--	--
Argentina	--	3	--	13
Brazil	--	6	1	18
Chile	--	4	--	8
Colombia	--	2	--	4
Cuba	--	1	--	2
Ecuador	--	2	--	2
Mexico	--	--	--	9
Peru	--	8	2	5
Uruguay	--	--	--	3
Venezuela	--	2	--	6
Sum	0	48	3	105

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APPENDIX

B

MATERIAL AND WASTE STREAM QUANTIFICATION - SUPPORT

Material and waste stream volumes

In the following, the volume distribution originating from the four different vessel categories are assessed. Priority groups have been focused upon.

Merchant vessels/ Inland waterway vessels

In order to establish some generic norm in relation to volumes of materials and wastes that normally are found in a vessel ready for scrapping, a VLCC has been investigated (ref.:/19/), since it is thought to be representative for the VLCC fleet that will enter the market over the next few years. The vessel was built in Europe in 1976 and had a carrying capacity of 290,000 DWT. Main groups of substances of environmental concern were identified and attempted quantified.

Anodes

For protection against corrosion and fouling a number of anodes are fitted to the vessel's hull and inside the tanks. According to the original specifications there were about 70,000 kg Aluminum (Al) anodes and 40,000 kg Zinc (Zn) anodes on board when the ship was first built. It has been found that 30-70 % of the original amount is likely to be left when the ship is ready for scrapping, hence our sample vessel would contain ~ 35,000 kg Al and ~ 20,000 kg Zn (the anodes will also contain small amounts of other metals including some heavy metals).

Batteries

Lead-acid batteries represent the largest volume of batteries on board and are found in radios, fire alarms, emergency start equipment, lifeboats, etc. The total weight (wet) of lead-acid batteries on the sample ship amounts to 232 kg, of which there were 140 kg lead (Pb) and 44 liters of sulfuric acid ($H_2SO_{4\,(l)}$). This amount is thought to be low in comparison with merchant vessels in general, since some vessels have configurations providing emergency lighting from a battery source in addition to a number of spare batteries.

Paints and coatings

Paints and coating are used on ships in order to protect against corrosion and fouling (subsurface hull) and are known to contain various environmentally hazardous substances, such as certain heavy metals, PCB and tin-organic compounds (ex. TBT). Documentation indicates that 65,000 liters of paints and coatings were used when the ship was built. A considerable amount of this is volatile compounds that will evaporate during coating. The amount left of the original paints and coatings has been estimated to be about 25 % on the hull/ superstructure and about 60 % on the inside of the vessel. However, due to accumulation caused by new applied paintwork following maintenance, the total amount of paint on the ship ready for scrapping is most likely more than the amount originally applied. The remaining TBT from anti-foulings was estimated to be 1,200 kg.

Another source gives an estimate of 3 liters of paints and coatings per GT of ship (ref.:/35/). Of this, 10% of the products used are polyurethanes, 15% are anti-foulings, 12% are shop primers (zinc silicates), and the balance is mainly epoxy based.

In Norway, the PCB content in paint used on vessels in the period 1950-1970 has been found to be approx. 5% (wet paint) (ref.: /38/).

CFC

The total amount of refrigerants on board was estimated to be approx. 1000 kg of R22 ($CHClF_2$) and Freon-12 (CF_2Cl_2), and was used in the control room, storage rooms, air conditioning systems and as spare.

Asbestos

Two ships were assessed with respect to asbestos content. The sample VLCC of 290,000 DWT contained about 7,000 kg asbestos and a 100,000 DWT chemical tanker had about 10,000 kg of asbestos. It must be noted that the vessel size is not necessarily decisive for heat insulation requirements in the engine room.

Steel

The amount of steel will vary according to ship type. Empirical methods suggest some 15 % of the DWT for VLCC and ULCC to be representative for the steel weight. The steel fraction will be somewhat higher for smaller vessels (ref.:/34/).

Since the relationships above are for very large ships only, some relationships between steelweight and deadweight that would be valid across a wider range of vessel sizes have been developed:

0.7-1.8 million tonnes steelweight equates to 3.6-9.0 million DWT.

This means that about 20% of the DWT represents the steel weight (Ref. Appledore).

Electrical installations

The approximately 50,000 meters of cables on board our sample ship contained an estimated amount of 45,000 kg copper (Cu), 10,000 kg PVC and 20,000 kg rubber.

PCB was detected in a cable sample from an on-site assessment at a ship scrapping yard in Bangladesh. It is not established if the PCB came from the original cable material or if the cable had been contaminated with PCB-containing oil (ref.:/20/). EPA has recently revealed maximum PCB-concentrations from cable samples taken from a vessel during scrapping at 280.000 ppm. Based on this, it seems likely to suggest that the configuration of cables arriving from vessels being decommissioned will most likely contain PCB in some quantities.

It has been shown that capacitors in light fittings may contain up to 30 mg PCB, and that fluorescent light tubes might contain up to 15 mg mercury (Hg) (ref.:/19/). Our sample VLCC had 481 light fittings and more than 1,000 light tubes, which yields a total of 14 grams of PCB and about 15 grams of Hg. There are also other sources of Hg and PCB on a ship that may contribute more to Hg- and PCB-containing waste, but these were not assessed in our sample ship.

Oil

The oil content (remaining onboard when beached) of the VLCC was estimated as follows:

Lubrication oil:	approx. 20,000 liters
Hydraulic oil:	approx. 18,000 liters

Heavy fuel oil:	approx. 333,000 liters
Oil sludge (sand, rust and oil):	approx. 2,000,000 liters

Offshore Structures

Data from seven installations in the North Sea has been compiled in order to establish a generic norm in relation to volumes of materials and wastes that are expected to be found in an offshore structure ready for scrapping (ref.: /25/).

Data regarding materials and wastes from the 7 installations have been summarised producing a "unit installation" which is an average installation of the seven studied installations. Although this is a coarse simplification, the method gives numbers that may give an impression of materials and wastes to be produced in the future from offshore installations.

An offshore installation may in general be divided into two main parts:

- Topside with different modules (drilling, helideck, living quarter, separation, utilities etc.) The topside may therefore contain several different types of materials and wastes.
- Jacket (steel structure with piles of steel filled with concrete).

Based on the evident difference between the topside and jacket the two parts have been studied separately.

Re-usable equipment

There is little information about quantities of re-usable equipment from offshore installations. However it may be assumed that pumps, valves, compressors, life saving equipment etc. from topsides may be reused, but this depends on the status of the equipment. It may be assumed that 1-5 % of the topside weight is equipment that may be reused. Correspondingly, it may be assumed that there are no directly reusable parts from the jacket. It should be emphasised that this is an estimate.

Recyclable material

Table 10-8 summarises the amounts of recyclable materials from topside and jacket. The table also gives amounts of recyclable material for a unit installation and for the 15 installations that are expected to be decommissioned annually for the next 15 years.

Table 10-8 Recyclable material from topside and jacket.

Item	Steel (tons)	Stainless Steel (tons)	Copper (Cu) (tons)	Aluminium (Al) (tons)	Concrete (tons)
Topside	3,481	190	238	8	14
Jacket	3,310			31	264
SUM "unit installation"	6,791	190	238	39	278
SUM 15 unit installations	**101,865**	**2,850**	**3,570**	**585**	**4,170**

As can be seen from Table 10-8 the amount of *steel* from offshore installations will constitute about 100,000 tons annually for the next 15 years. The topside and the jacket have in a unit installation about the same amount of steel. The *stainless steel* originates from equipment, coverings etc. exposed in such a way that additional anti-corrosive activity is required.

The amount of *copper* originates mainly from electrical cables on the topside.

Aluminium originates mainly from anodes on the jacket. The anodes consist of about 98 % Al and almost 2 % sink (Zn). Thus the weight of aluminium given in Table 10-8 constitutes almost the weight of the anodes.

Concrete consists mainly of grouting in the piles in the Jacket of the steel platforms. It is debatable whether concrete could be recycled or if it should be regarded as waste material. In this study it is however assumed that the concrete may be used e.g. in construction of roads, as filling material etc. and hence it is regarded as a recyclable material. Whole concrete installations are not discussed here.

<u>Waste material</u>

Table 10-9 summarises the amounts of waste materials from topside and jacket. The table also gives amounts of waste material for a unit installation and for the 15 installations that are expected to be decommissioned annually for the next 15 years.

Table 10-9 Waste material from topside and jacket.

Item	**Wood (tons)**	**Structural water (tons)**	**Marine growth (tons)**	**Rest (tons)**
Topside	1.4			318
Jacket		376	367	
SUM "unit installation"	1.4	376	367	318
SUM 15 unit installations	**21**	**5,640**	**5,505**	**7,770**

Wood mainly originates from furniture, walls etc.

The structures of the jackets are often water filled (*structural water*). Corrosion inhibitors (biocides) are added the water in order to avoid corrosion. In certain cases it will be allowed to discharge this water to the sea.

The amount of *marine growth* varies depending e.g. on the water depth. The marine growth constitutes a large amount of sessile organisms that grow on the jacket and represents waste that has to be treated onshore.

As can be seen from Table 10-9 the *rest* column constitutes an extensive number. In Table 10-10 the most important waste materials in the rest column is partly specified. It should be emphasised that the numbers in Table 10-10 is both given as tons, kg and numbers of units.

Table 10-10 Specification of some waste materials from the “Rest” column in Table 10-9.

Item	Paint (tons)	Insu-lation total (tons)	As-bestos in insul. (tons)[1]	Plas-tic in cables (No.)	Light tubes (No.)	Radio-active smoke detector (No.)	Cd, emer-gency light battery (kg)	Ni, emer-gency light battery (kg)	Oil filled trans. (No.)	Level switc (No.)	Hal-on (kg)	CFC’s (kg)
Topside	32	54	13	60	1,357	15	45	65	1	24	74	57
Jacket	19											
SUM “unit installation”	51	54	13	60	1,357	15	45	65	1	24	74	57
SUM 15 unit installations	**765**	**810**	**195**	**900**	**20,355**	**225**	**675**	**975**	**15**	**360**	**1,106**	**857**

[1]: Calculated based on an assumption that 0.3 % of topside weight is asbestos/26/.

Paint is one of the main contributors to the rest column in Table 10-9. The types of paint used will vary considerably.

Insulation is the generic term for e.g. mineral wool and asbestos. *Asbestos* has been calculated assuming that 0.3 % of the topside weight is asbestos.

The *plastic* number given is only for plastic in cables. No other number has been available with regard to plastics.

One *fluorescent light tube* contains approximately 15 mg of *mercury* which means that the tubes have to be treated as hazardous waste.

Based on available information there are only some models of smoke detectors that may contain a *radioactive* source. Numbers of such items are given in Table 10-10. Another source of radioactive material is scale, which may be found in e.g. main processing pipes on the installations. However there have not been any available numbers with regards to amounts of such scale on offshore installations. In addition it should also be noticed that in emergency exit plates there might also be a radioactive source. However many of these plates will be removed beforehand. No numbers are available.

Batteries in the emergency light fittings contain *nickel and cadmium* and the amounts are summarised in Table 10-10. However there are also battery rooms with battery packages on the installations. These batteries are much larger and consist on average 7 weight-% cadmium and 8 weight-% nickel. From other sources (ref.: /27/) than the one referred to with regard to emergency light fittings (ref./25/), it may be assumed that the cadmium and nickel content in the emergency light fitting batteries constitutes about 15 % of the total content of all batteries on an installation. Hence the amount of nickel and cadmium per unit installation is about 4.5 tons and 6.5 tons respectively. In addition there is an *alkaline electrolyte* solution in these batteries mainly consisting of potassium hydroxide (KOH) and small amounts of lithium hydroxide (LiOH) in distilled or de-ionised water. On a unit installation there will be about 4,500 litres of such electrolyte (ref.: /27/). In addition it should be noticed that there are *lead* batteries in lifeboats, MOB boats and on air compressors. These batteries consist on average of about 90 % lead. On a unit installation it may be assumed that there will be about 450 kg lead in such batteries.

Transformers are either oil cooled or air-cooled. A unit platform will on average have one oil cooled transformer. The oil in the transformer may have *PCB containing oil*. However often this oil has been changed during maintenance and hence the PCB-containing oil may have been replaced. It should however be noticed that there might be traces of PCB in the changed oil. If the oil contains more than 50 ppm PCB the oil has to be treated as hazardous waste.

Old level switches could contain*mercury*. In recent years the use of mercury in level switches has decreased. However most of these level switches have a long lifetime and thus it should be expected that some switches are original. The switches should be opened in order to verify the Hg-content. Content of mercury in each level switch varies. No numbers are available concerning the content.

Halon may be found in fire fighting systems but has for most installations been phased out already.

CFC's may be found in refrigeration plants in fixed and portable units. Originally these were filled with CFC's that are damaging to the environment. However due to phase-out of these refrigerants, all refrigeration plants should have been recharged with alternative refrigerants. The numbers given inTable 10-10 are only given for fixed units. The portable units (fridge's, freezers, small water coolers and ice machines) contain about 0.1 to 0.4 kg of CFC per unit. The refrigeration units additionally contain an amount of oil and not uncommonly an amount of mercury in switches. Amounts are assumed to be very small. The number of units onboard a unit installation is not identified. However portable units can be sent ashore for recycling without opening the refrigeration system.

Hydrocarbons and chemicals (except halon and CFC's) are not included in the list of wastes that have to be treated. The amount of hydrocarbons and chemicals will vary considerably with the different fields and types of installation, and thus it is not possible to estimate numbers for a unit installation.

Naval vessels

Whilst it has been possible to develop general assumptions for the size range of vessels common to the west European navies, no data exists regarding the much larger warship types found in the ex-Soviet and US navies (see table below).

Table 11 "Typical" west European naval ship data

Ship Type	LOA	B	Draught	Depth	Steelweight	Lightship /Std Dispt	Full Load Dispt	Steelwt/ Dispt
Submarine	78				781			
Patrol Craft	63	10		5,5	329	583		56 %
Corvette	83	11,5	3,4	7,2	438	1103		40 %
T22 Frigate	148	14,75		9,41	1775			
T23 Frigate	133	16,1	5,5	9	1264	3500	4200	36 %
Canada Frigate	134	16,4	4,6	11,4	1700			
Frigate	137	15,55	5,78	11,58	1370	4382		31 %
T42 Destroyer (short)	125	14,3	6,4	9,7		2991		
T42 Destroyer (stretched)	141	14,9	5,8	9	1283	3500	4775	37 %
T45/CNGF	145	20,5	5	11,8	2300	4916		47 %
Ocean Survellance	65	13,1	4,3	6,1	763	1364		56 %
Fleet Oiler US	180	26,82	9,75	14,83	6586	9198		72 %
Fleet Oiler US	207	29,75	10,52	15,24	10928	14946		73 %
Helicopter Carrier	129	18,68	4,41	15,25		4470		0 %
Aircraft Carrier (Illustrious) approx.	206,6	27,5	6,4		11500	19500		59 %

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