Pollution due to Shipping & Other Marine Industries and Corresponding Mitigation Measures.

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Mission
Assurance of Optimum Performance with Design, Innovation & Technology.

Vision
A Sea of Technology

Agenda

- Pollutions caused by Shipping & other Marine Industry
- International Regulations in place for Shipping :
  - Current / Future requirements
- Various technologies / Mitigation Measures :
  - Available currently / Expected in the near future
- Pollution hazards from other Marine Industry
- Corresponding Mitigation measures

CLIMATE CHANGE

- It is real for sure, its already happening
- Some effects maybe irreversible
- Little has been done so far, - started perhaps too late
- Paris Agreement 2015 is a landmark decision
- However, is the response sincere & Actions enough
- Looking forward, we have no time to waste
- Response from Shipping Industry - Substantial and Implementation / Compliance – Excellent

IMPORTANCE OF SHIPPING INDUSTRY

- Most Essential Industry for Global Business
- Over 90 % of world trade is carried across the world's oceans by about 95,000 seagoing ships
- Nearly 12 Billion Tonnes of Cargo in 2020
- Average Growth in Shipping is about 3 % per year

POLLUTION DUE TO SHIPPING

Mainly Pollution to :

- Air (GHG)

  (Controlled by MARPOL Regulations – Annex VI)

- Seas (Oil, Chemicals, Biological, Garbage)

  (Controlled by MARPOL Regulations – Annex I to V

  and also by SOLAS)

(A) AIR POLLUTION BY SHIPPING INDUSTRY

Rise in GHG - Main cause for the climate change

Share of Shipping Industry :

- About 1000 Million Tonnes of CO2 /Year (About 3 % of global CO2)
- About 2.5 % of global GHG
- If Shipping Industry was a country, it would be ranked 6th !

GREEN HOUSE GASES & SHIPPING INDUSTRY

- Shipping Industry has to do its share to control GHG
- In a fiercely competitive world……

  Only Statutory Regulations work !

Accordingly, IMO has laid down :

- **Mandatory Regulations** in respect of the CO2, Nox, Sox, CFCs,
- Set Short Term & Long Term **Targets** for GHG Reductions

CONTROL OF GHG DUE TO SHIPPING

- **Short term** Targets 2020 – 2025 Regulations in place
- **Mid term** Targets 2025 - Regulations are in Place, may require to tweak (bring forward / make more demanding)
- **Long term** - Only Targets till 2050 – detail measures TBD
- Even short term measures are demanding
- Long term measures require a huge change in Industry
- Every means need to be explored – Multipronged Approach required

AIR POLLUTION : NOX EMISSIONS

Caused by reactions of Nitrogen & Oxygen in combustion air at **High temperatures** in Marine Engines

- Permissible Nox emission :
  - 17.0 g/kwhr for slow speed engines (< 130 RPM) &
  - 9.8 g/kwhr for high speed engines (> 2000 RPM)
  - By interpolation for in between RPMs

MITIGATION MEASURES : NOX EMISSIONS

1. **mid Air Method**: In this method, water vapour is mixed in the combustion air before supplying it to the cylinder. Can achieve reduction of NOx by 70-80%.
2. **Selective Catalytic Reduction:** Exhaust gas is mixed with Urea Solution & then passed through catalytic convertor. Most efficient method (90-95% reduction).
3. **Exhaust Gas Recirculation** is not so effective.

AIR POLLUTION : SOX EMISSIONS

Caused during combustion process due to presence of Sulphur in Marine Fuels.

Current Regulations allow control of SOX emissions by:

a) Use of Low Sulphur Fuel Oil or

b) Installation of Exhaust Gas Cleaning System which is approved for compliance with the MEPC Guideline ensuring equivalence to LS Fuels

MITIGATION MEASURES : SOX EMISSIONS

1. **Use of Low Sulphur Fuels**: Sulphur limits :

   0.1% by weight in ECA areas and

   0.5% in General areas (reduced from 3.5% in 2020)

   Easiest Option but is it Expensive ?

2. **Exhaust Gas Scrubber Technology:** 95% Reduction.

   Exhaust gas is passed through a scrubber where a liquid (solution of FW and Caustic Soda) is showered over it.

Even though Fuel is normal - Not a popular choice.

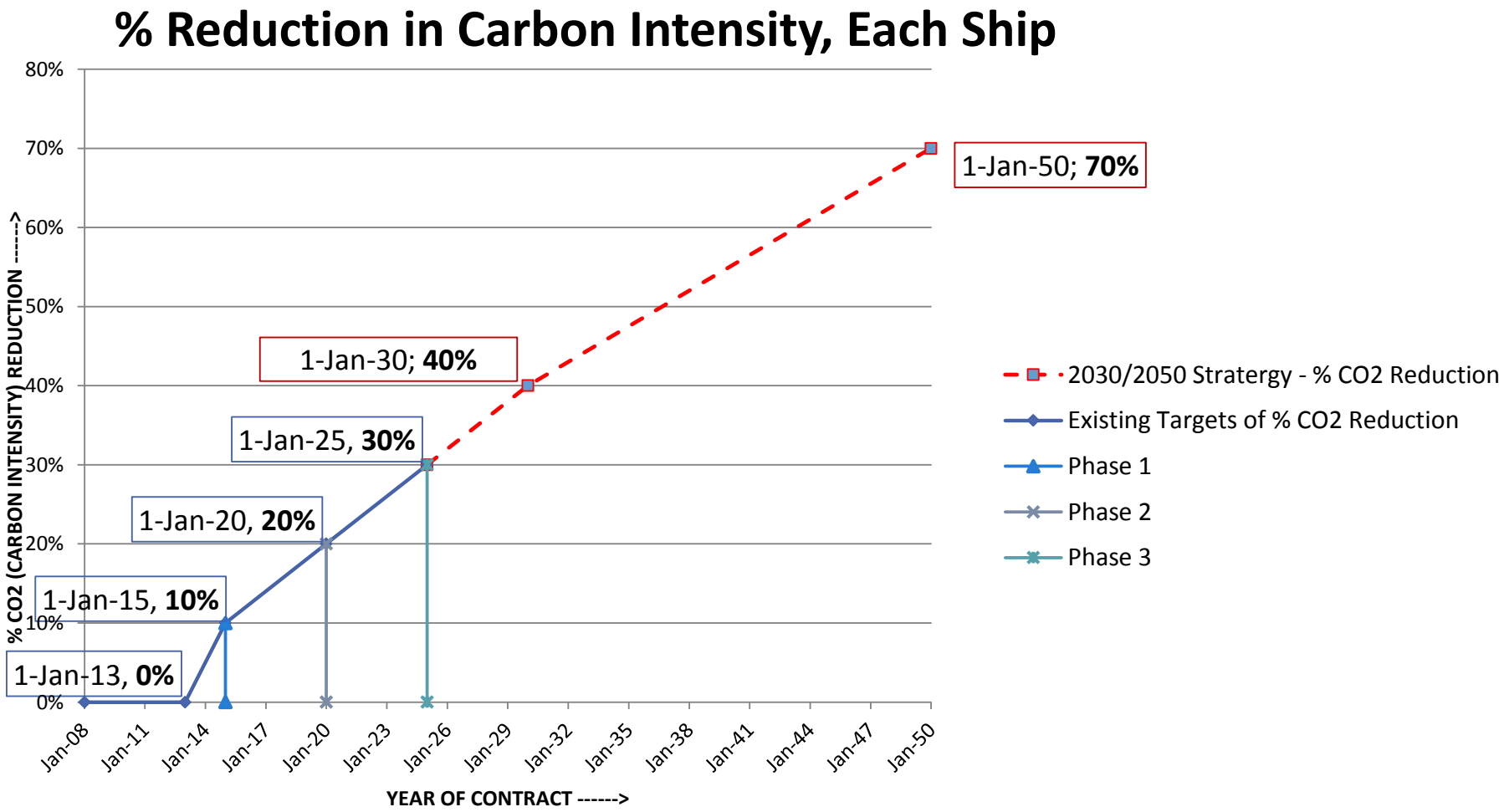
AIR POLLUTION : CO2 EMISSIONS

- CO2 is perhaps Most important component of GHG
- CO2 Reduction : Much Tougher Task
- Shifting Targets
- Regulatory limits for Individual Ships (EEDI)
- Target for the Whole Shipping Industry

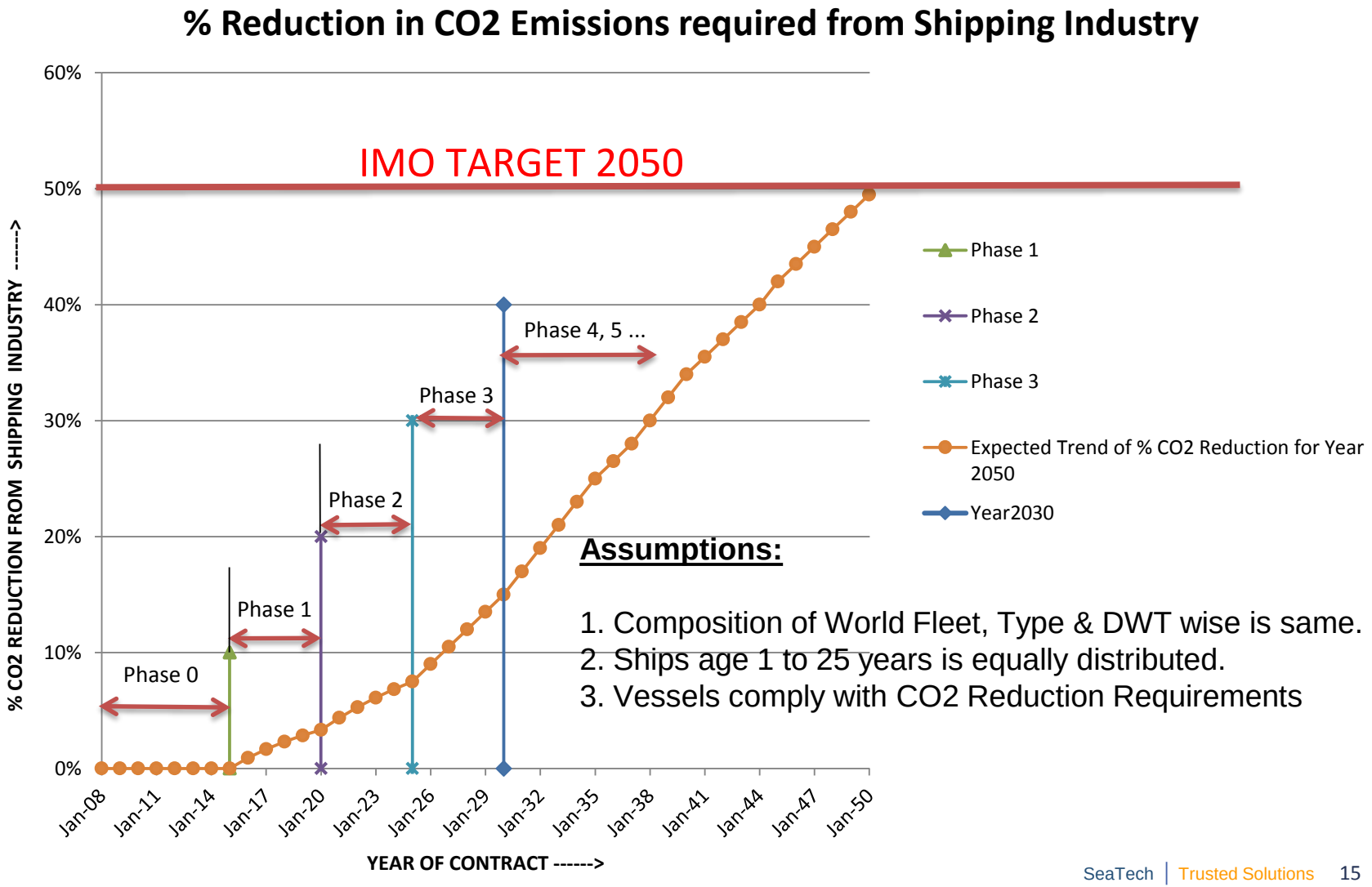
  (IMO Strategy for 2030/2050)

Source: Marine Insights

Individual Ship Requirements & Targets



Target for Shipping Industry



Assumptions:

1. Composition of World Fleet, Type & DWT wise is same.
2. Ships age 1 to 25 years is equally distributed.
3. Vessels comply with CO2 Reduction Requirements

Message is clear >>>Reduce Fuel with Carbon Footprint

Main strategies to achieve this :

1. Better Ship Design
2. Better Ship Operations
3. Use Alternate Fuels – Zero or Low Carbon Fuels
4. Use Alternate Energy Sources
5. Structural Changes to Shipping Industry
6. Carbon trading ?

Remember the target for each ship is **70%** reduction of CO_2

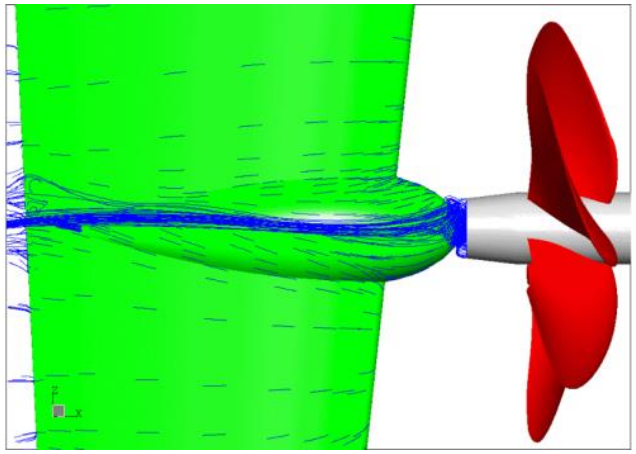
1. Better Hull Form

- Currently the hull forms are already fairly optimized, Increased draught of the vessels with deeper canals and ports can open up better opportunities
- Similarly larger vessels can bring down power & energy spent/ tonne
- Overall further potential about ≈ 4-5 % max

2. Better Propeller Design

- Currently Conventional Propeller Designs are already fairly optimized
- Increased draught of the vessels can mean increased propeller dia which may be helpful if the engine/ shaft RPM can be reduced
- However, further improvement using CFD analysis, wake –adapted, high efficiency propellers is possible.
- Overall further potential abt ≈ 5 -6 %

3. Energy saving Devices



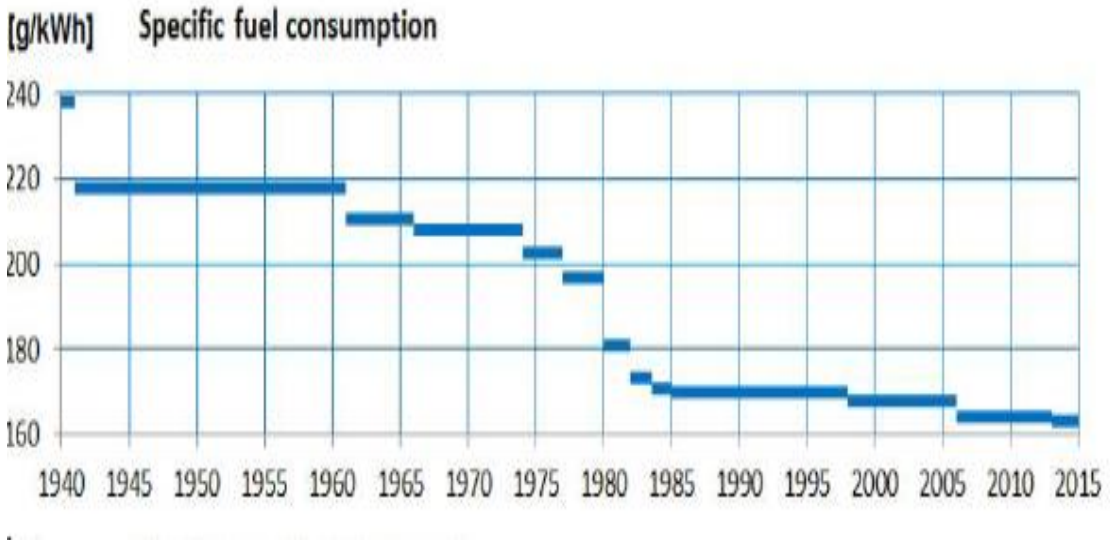
Rudder Bulbs	up to 2 %
Propeller Boss Cap Fins	up to 3 %
Wake Equalising Fins/Duct	up to 4 %

(Note : All options can not be applied simultaneously)

Source: Marine Insights

4. Better Engines

- Increased Engine Efficiency
- SFOC for slow speed engines has come down from abt 180 gms/kW- hr to about 160 gms/kW-hr in last 30 years.
- What's possible next ?

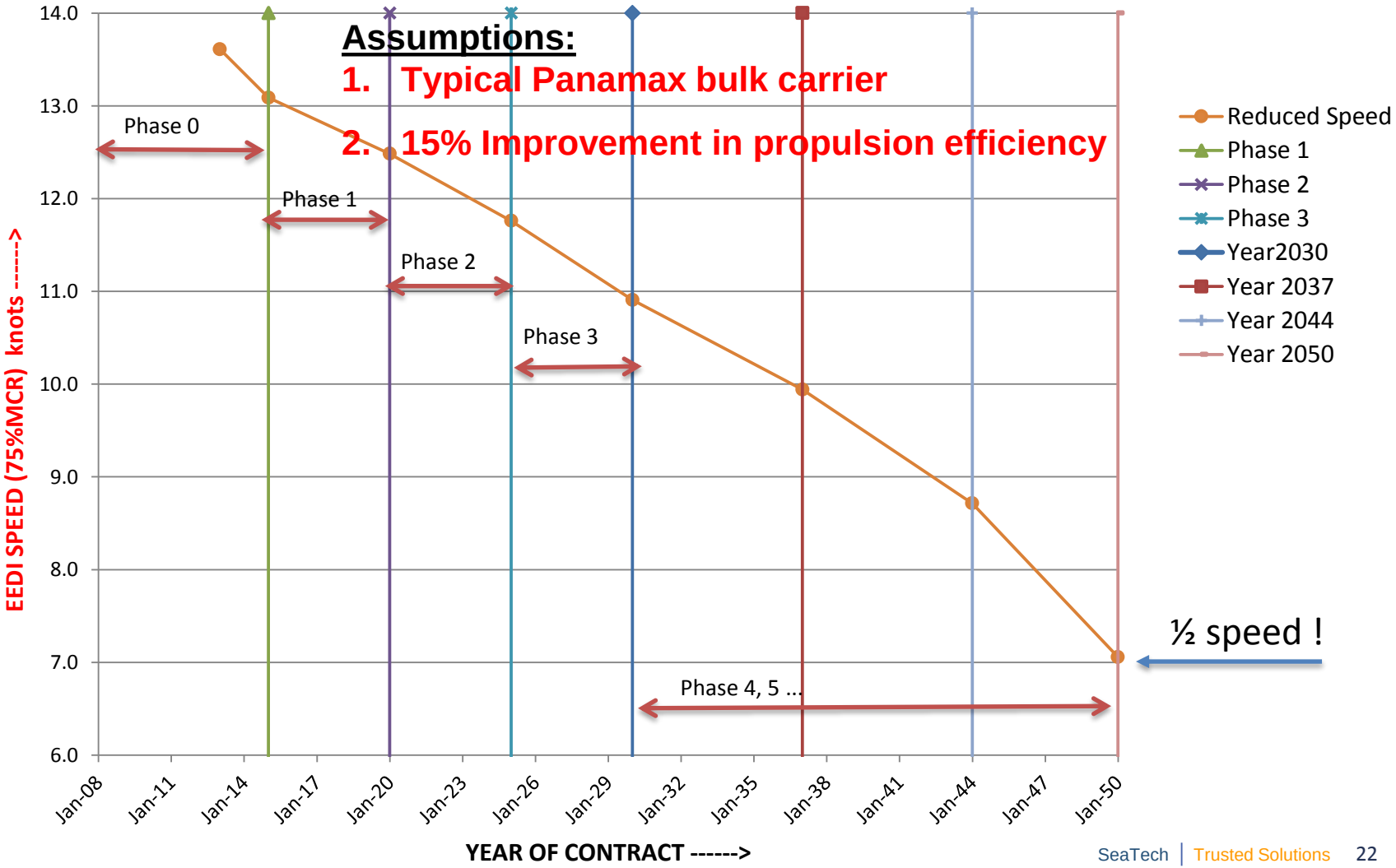


Source: Marine Insights

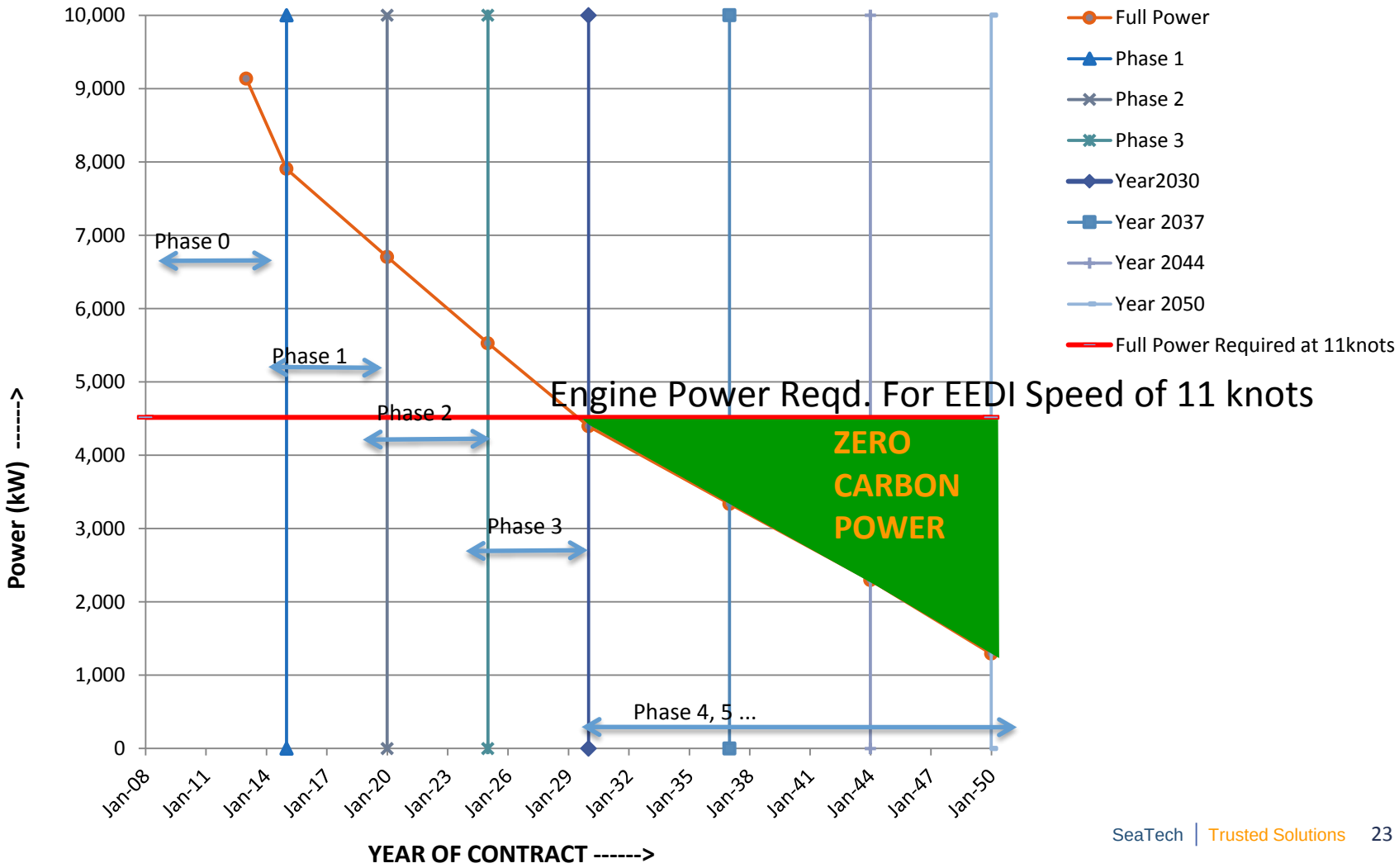
5. Speed Reduction

- This is perhaps most effective measure
- Easy to implement, especially for existing ships
- 15% speed Reduction means 30 % Reduction in Fuel/Mile
- However, the speed & power can not be reduced too much
- Minimum Power Required as per MEPC Circ. 850
- Therefore Propulsion needs to be supplemented by **Zero or Low Carbon Energy**, in later Phases 4, 5 (2030 to 2050)

Speed Reduction Required to Meet EEDI / IMO 2030-2050 Targets



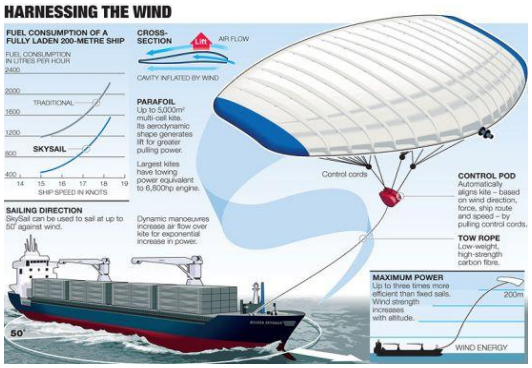
Zero Carbon Power Assistance Required to meet EEDI/ IMO 2030-2050 Targets



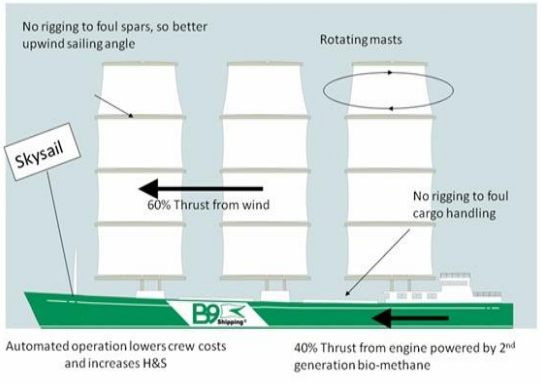
Alternate Energy Sources are Certainly Required

Direct use of Wind on ships – up to 7% Savings

Maersk Pelican
up to 7% Savings reported with 2 Rotor sails



Sky Sails / Kite Ship



B9 Windpower Technology

Source: Marine Insights

Low Carbon Fuels

- Biofuels
  - Current technology can be used
  - Provided we don't destroy forests
- Electric Power Batteries
  - Storing Renewable energy
  - Many sources of Renewal energy
- Hydrogen for Engines or Fuel Cell
  - Provided Renewable energy is to obtain the Hydrogen

Source: EESI

Alternative Fuels - Hydrogen

- Liquefied Hydrogen is promising as a Low - to Zero-carbon fuel for meeting the IMO GHG target for 2050.
- Potential use in IC Engines and Fuel Cells.
- Renewable energy, which has very low carbon footprint can be used to generate hydrogen through electrolysis.
- Hydrogen can produce electricity through fuel cells and combustion technologies.
- However, hydrogen carries various challenges of advanced storage requirements and fire hazard mitigation.

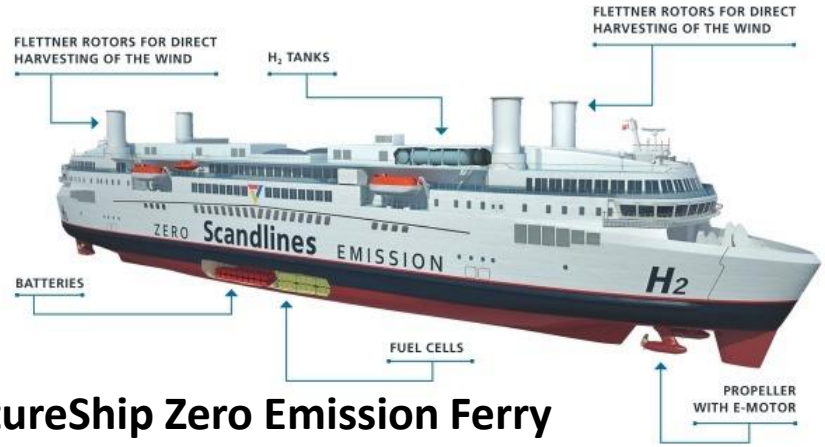
Alternative Fuels - Hydrogen

- As competitive alternative marine fuel, hydrogen must be available at ports at both low cost / low carbon footprint.
- Hydrogen has highest energy content at 120.2 MJ/kg, which is 2.8 times that of MGO in terms of mass energy.
- But, on volumetric basis, liquid H2 requires 4.0 times more space than MGO or 2.0 times more space than LNG.
- Further Hydrogen requires to be stored at extremely low temperatures below -255° C. So space requirements are even more considering cryogenic insulation provisions.

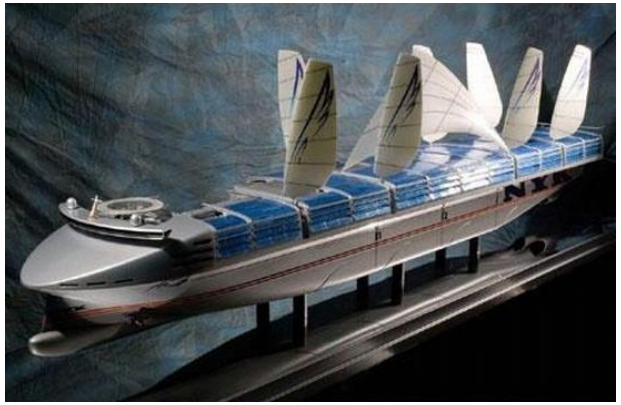
Zero Emission Ships

- Several Projects on the Anvil – started by reputed companies
- Using Multiple Zero Carbon energy sources
- Electrical Batteries charged by Renewable energy from land
- Hydrogen Fuel cells
- Wind and wave power

E/S Orcelle – Car Ferry



FutureShip Zero Emission Ferry



Super Eco Ship 2030 NYK

Source: Marine Insights

Other Opportunities for Saving Fuel / Reducing Carbon Footprint

Weather Monitoring & Route Planning

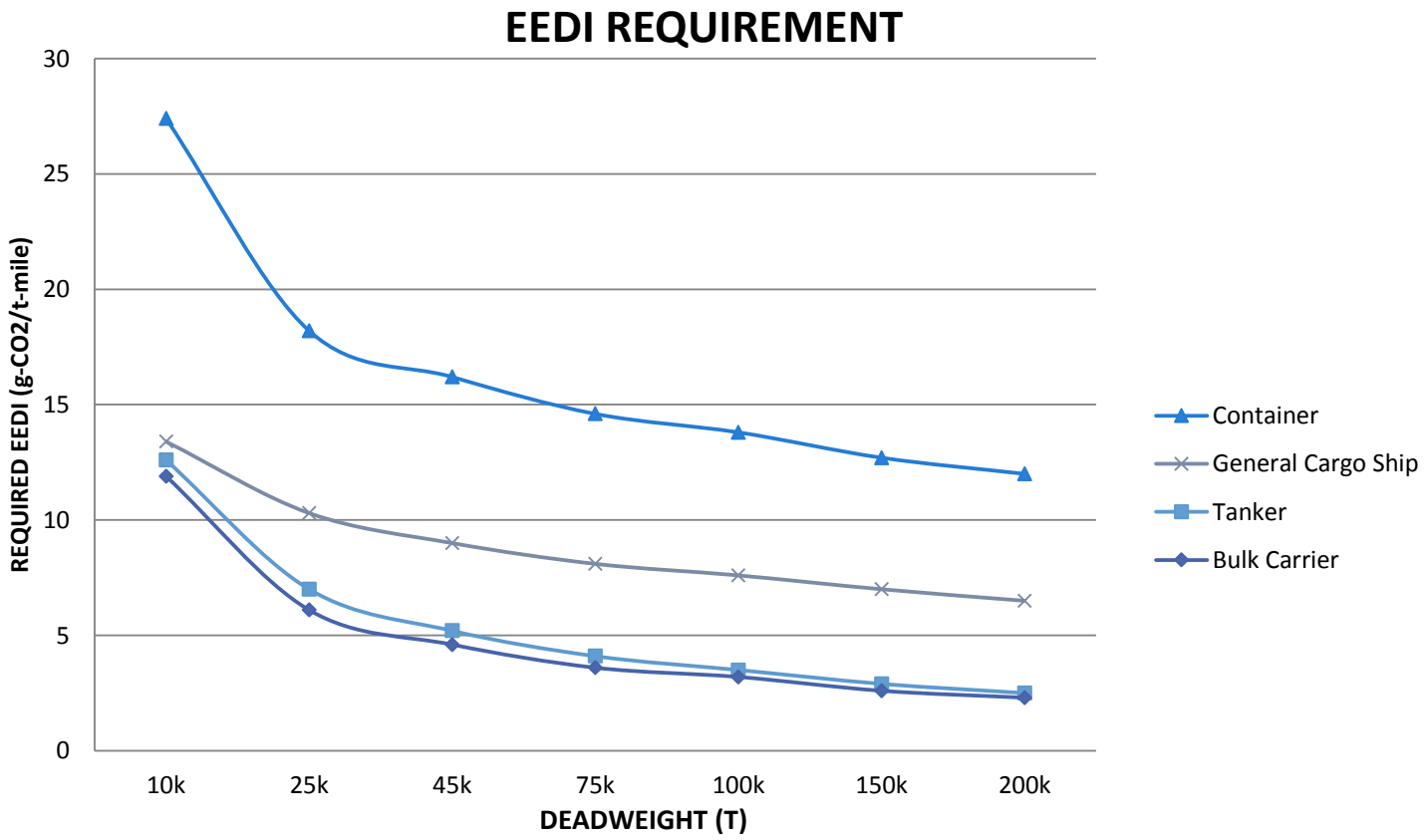
- Monitor the weather/ forecasts
- Real-time scheduling and route planning data
- Plan and avoid bad weather
- Choose the most optimal route

(Reduce extra fuel in adverse weather)

Other Opportunities for Improvements

- Better materials for Lighter ships >> increased deadweight
- Better port facilities
  - Availability of Zero carbon Renewable energy
  - Deeper draughts, better ship economy
  - Better infrastructure to do all cargo handling & using shore power
- Bigger & Slower Ships for the long haulage

5. CO2 Limits and Ship size



1. **Bigger, Slower** Ships will help meet the Industry target of 50%
2. Transport of **Finished goods** cause 3.5 times emissions that by **Raw materials**

(B) SEA POLLUTION BY SHIPPING INDUSTRY

Sea Pollution by Shipping Industry in many ways :

Oil Pollution/ Bilge Oil Pollution – Major Concern

- Dirty fuel oil finds way to bilges which mixes with sea water when discharge. IOPP Regulations to control discharge.
- Oil spills in major Accidents. MARPOL & SOLAS Regulations for Cargo Space Protection & Damage Stability

(B) SEA POLLUTION BY SHIPPING INDUSTRY

Ballast Water Pollution

- Ballast water is required for empty return voyage for draft, trim & stability
- Taken from one port and discharged elsewhere spreads alien microbes and marine organisms polluting (disturbing) the local fauna.
- Regulations require approved BW Treatment systems.

(B) SEA POLLUTION BY SHIPPING INDUSTRY

Sewage/ Blackwater/ Grey Water Pollution

- Waste water from toilets, showers, sinks, laundries & galleys etc. carries lots of Bacteria and Chemicals.
- However due to it's volume generated over voyages, it has necessarily to be dumped into sea.
- MARPOL Annex… specifies the requirement of the Sewage Treatment that is required on ships.
- Only after treatment, the waste water is discharged into sea, while the ship is moving.

(B) SEA POLLUTION BY SHIPPING INDUSTRY

Solid Waste Pollution

- Solid Waste materials include packings, bottles, cans, plastics, food waste, rags, metal scraps etc.
- Ships adhere to **Zero Dumping Policy** when sailing.
- MARPOL Annex 5 requires Approved Garbage Management Plan.
- Incinerators and Compactors are used.

POLLUTION BY OTHER MARINE INDUSTRIES

(C) POLLUTION BY OFFSHORE OIL & GAS INDUSTRY

- Important Global Industry – 33% of Oil & Gas Comes from Offshore
- Dominated by Oil Majors
- Mostly governed by National Regulations
  - which Vary in Issues addressed and in the detail
- No global regulating liability & compensation for pollution resulting from offshore drilling activities

OFFSHORE OIL & GAS : POLLUTION CONCERNS

- Ships, Drill Rigs and Oil platforms
- For Ships servicing Offshore Oil & Gas the Pollution Concerns are mostly same as Tankers
- Additional codes such as OSV code for Supply Vessels & MODU code for Mobile Drilling Units address risks
- Reputed Industry standards followed Internationally

  - API, NORSOK, Classification Societies Rules

OFFSHORE OIL & GAS : POLLUTION CONCERNS

- OIL SPILL from wells is the most important concern
- BOP – Blow Out Preventer is a large & heavy specialized unit which iss fitted at top of oil wells.
- When activated it is supposed to seal off the well quickly- in minutes, and prevent any oil
- BOP is designed with extra redundancy – usually SIX independent mechanisms to shut it close.

DEEPWATER HORIZON : BOP FAILURE

- Deepwater Horizon a Semi-Submersible Drill Rig
- April 2010 -Gulf of Mexico Worst environmental disaster
- 11 Men dead, 17 injured, 100 escaped the burning Rig
- Deepwater Horizon sank 2 days later, leaving the well spewing oil & gas in Gulf waters for ***87 days***
- 780 Million Liters of oil spilled, hundreds of miles of coastline damaged – still recovering.
- BOP failed due to “ Buckled ” Drill Pipe

(D) SEA POLLUTION BY FISHING INDUSTRY

- Fishing Vessels pollute in same ways as all other ships.
- Additionally they pollute by discarded not- marketable trash fish + unwanted remains on fish factory ships.
- The bottom fishing method - dragging a heavy beam on the seabed is very harmful & destroying natural habitats Fish farming uses antibiotics which are released along with the waste into the marine ecosystem.
- Sustainable aquaculture practices are encouraged

POLLUTION DUE TO TYPICAL DEEP SEABED MINING ACTIVITY

POLLUTION DUE TO TYPICAL DEEP SEABED MINING ACTIVITY

SCARICITY OF RARE EARTH MINERALS

ABUNDANCE OF MINERALS ON SEABEDS

- Polymetallic Nodules, Manganese Crystals, Sulfide deposits
- Copper, Gold, Silver, Nickel, Cobalt, Rare Earths

Manganese Nodules

Cobalt-rich Crusts

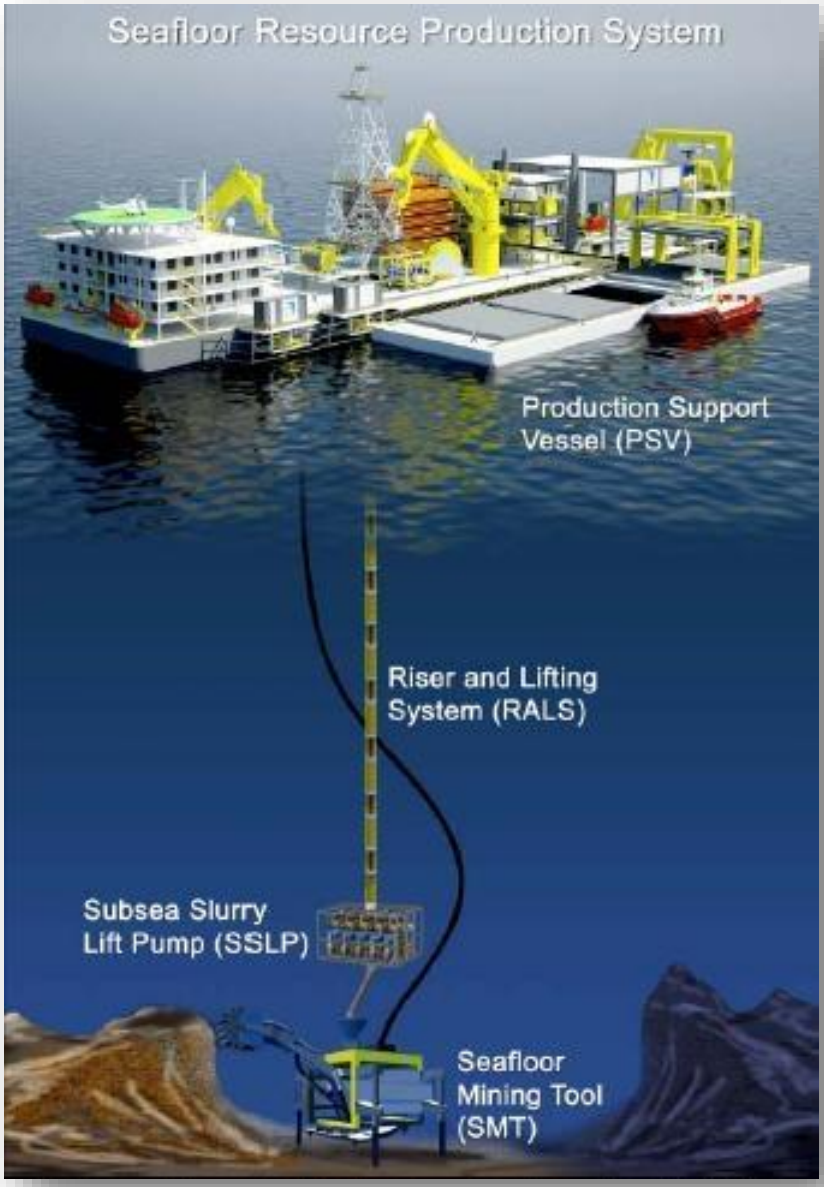
SMS

DIFFERENT METHODS OF EXTRACTION

Overall Logistics of DSM

1. Gross mining on seabed
2. Preparation of ore for uplift
3. Uplift
4. Processing Ore onboard
5. Storage of Ore on-board
6. Offload to Export Vessel
7. Delivery to onshore facility
8. Crew transfer
9. Supplies to Mining Vessel
10. Supplies to field vessels

Source: Nautilus Minerals



World's First Deep Seabed Mining Vessel

- Mining 2000m under water
- 227m x 40 m x 18.2 M (T=13.2m)
- 30MW - Diesel-Electric
- Dynamic Positioning
- 200 Men
- 4000T of Ore/day

World's First Deep Seabed Mining Vessel

Source: Nautilus Minerals, 2008

Main equipment for Deep Sea Mining

Mining Machines	• Disaggregate • Gather mineralized material
Slurry Lift Pump (SSLP)	• Slurry (ore + seawater) • Pumped to the mining vessel
Dewatering Plant (DWP)	• Separate ore from seawater • Ore delivered to the holds for storage
Cargo Handling System	• Most complex System : No Hatches ! • Offloading to bulk carrier
Export Vessel	• Bulkcarrier Moored alongside • Safe Approach & Transshipment at sea

Huge Mining Machines (ROVs)

Auxiliary Cutter (AC)

Preparatory machine

Deals with rough terrain

Creates benches for other machines to work.

Bulk Cutter (BC)

Higher cutting capacity

Limited to working benches created by the AC

Collecting Machine (CM)

Collect cut material (sand, gravel, silt)

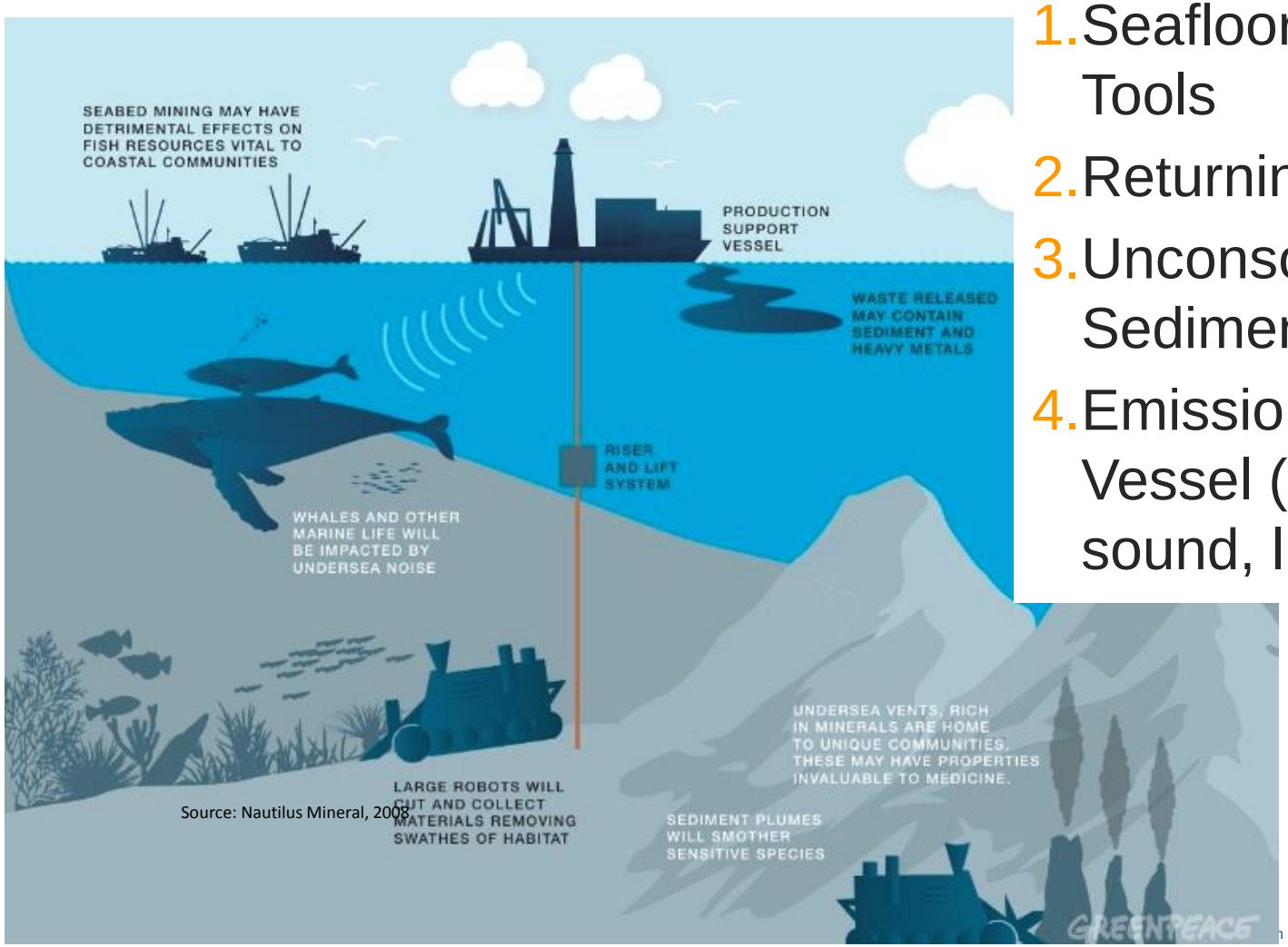
Draw in and Push slurry with internal pumps & through a flexible pipe to RALS

Riser and Lifting System (RALS)

- A large pump and rigid riser pipe hanging from vessel
- Delivers the slurry to the surface
- Deployed down by a derrick and draw-works

Source: Nautilus Minerals,

Environmental Impacts



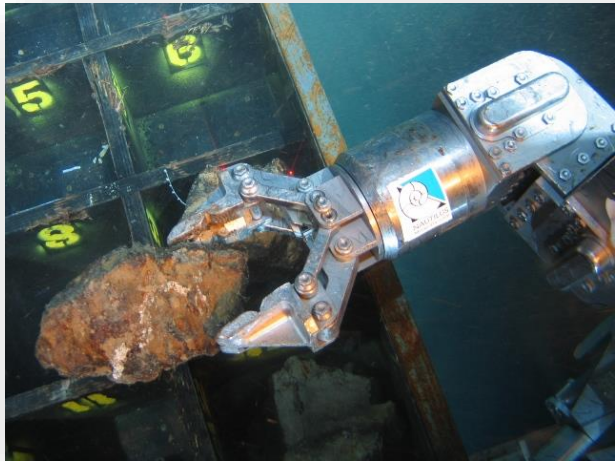
Source: Nautilus Mineral, 2008

4 Main Causes :

1. Seafloor Mining Tools
2. Returning Water
3. Unconsolidated Sediment Disposal
4. Emissions from the Vessel (oil, water, sound, light, etc.)

Mitigation Measures :

- Evolve a “ Fit for Purpose” Mining Method
- “Do minimum” – Least disturbance
- Innovate & Optimize mining and lifting process
- Handle solid components only ?
- Eliminate energy consumption in lifting up seawater
- Reduce demands on Mining Vessel



GENERAL CONCLUSIONS

- Meeting Carbon emissions is very UNIQUE for Shipping.
- Though demanding, shipping industry has complied with the regulations so far and will in the next decade as well.
- The overall efficiency of the conventional propulsion system can be improved by up to about 15-20% by improving all aspects - hull form, propeller, engines, ESDs etc.
- However, this + speed reduction, may be just about enough to meet the Phase 2 & Phase 3 requirements only.
- After EEDI Phase 3, i.e. Year 2030, Assistance from Zero Carbon Energy will certainly be necessary.

GENERAL CONCLUSIONS

- By 2050, the Zero Carbon Energy share will be nearly 75% of the total power required, even after speed reduction
- The major thrust is expected to be on development new propulsion systems using Stored Renewable Energy directly, or indirectly e.g. using Liquid Hydrogen
- This will be exciting new technology, a major revamp of traditional ship designs is expected.
- The future of Oil and Gas Industry will be on decline.

  Which means lesser funds for safety which means more vigilance & strict compliance with efficient SOPs.

GENERAL CONCLUSIONS

- Pollution of Seas is getting more attention and more stringent and actionable regulations are expected.

- Emerging marine industries like Deep Seabed Mining are very challenging environmentally and are being closely watched and monitored world wide. It will have to be environmentally safe.

- Finally, dedicated action on all fronts and on ground is the necessity for future generations to come –

Let us all pledge to make our world greener !

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