Fuel – Energy in Ports

Maritime Industry

Cold Ironing

AN OVERVIEW

by Capt. Pawanexh Kohli

Crosstree techno-visors

Global Backdrop

- Ships traditionally not subject to emissions control.
- Ships require electric energy even while in port.
- Diesel engines are the principal source of power for ships.
- Ships burn furnace oil (HFO) for captive electricity.
- One ship pollutes as much as 50 million cars annually. Studies (in 2007) indicate 60,000 of cardio-pulmonary mortalities due to ship emissions.
- **New Laws** now require **emission control on ships.**
- Ports across the world are exploring shore-to-ship power capabilities – drydocked merchant ships & some navies already switch to shore power.
- Business opportunity lies in providing **electric energy** to ships in Indian ports – this can include **potable water and steam.**

Power Generation in Ports

Energy Costs for Ship Owners

- Average 100 days in port in a year per ship.
- Average 5 MT of fuel consumed per day in port.
- Average cost of bunker fuel USD 265MT (Q1 2009).
- Per annum cost in port per ship: USD 132,000/-.
- Total world trading fleet 50,000+ merchant ships.
- Global cost, electric power in port, USD 6.6 billion.

  (Rs 33,000 crores)
- In 2008 top 13 ports of India, a total of 20,826 berthings occurred – India opportunity greater if considering various smaller ports and Indian navy.

Trends – Maritime Fuel

- IMO regs Mandates use of <4.5% sulfur fuel effective 2010 – ship owners suffer due to higher fuel cost.
- To reduce world maritime sulfur output to <0.5% by 2020
- In SEC Areas: target 1% by March 2010, 0.1% in 2015.
- Special fuels cost higher by USD 150 to 200 per MT; increased costs in port >$1500/- to 6000/- per day per ship.

Region/Year	Sulfur Targets - MARPOL [Revised Annex VI]			
	2010	2012	2015	2020
Global	4.50%	3.50%	-	0.50%
SECAs	1%	-	0.10%	-

- Some regions (eg. California) already require ships switch to clean fuel in local waters.
- Ship owners shocked by unprecedented targets, limited in choice and would prefer cheaper 'cold-ironing' whilst in port.
- IEEE Standards of shore-ship connections underway.
- Ship owners require cheaper, compliant source of electric power to meet global laws and to reduce insurance costs.

Marine Fuel Consumption

- Motive Power on Ships [15 to 200 MT / day].
- Auxiliary Power – electricity [2 to 30 MT / day].
- Fuel typically contributes 80% to 90% of variable costs for ship operators.
- Current global bunker consumption ~350 million tons.
- Fuel used is Heavy Oil (Bunker Oil), trend was to go for cheaper high CST grades (more polluting).
- In ports, auxiliary engines continue to run to power ancillary systems and cargo operation equipment.
- Average size container ship consumes 10 tons per day in port for power needs.
- New Intnl Regulations require use of low sulfur grades.

What is 'Cold-Ironing'

SHORE-POWER or cold-ironing and hotelling

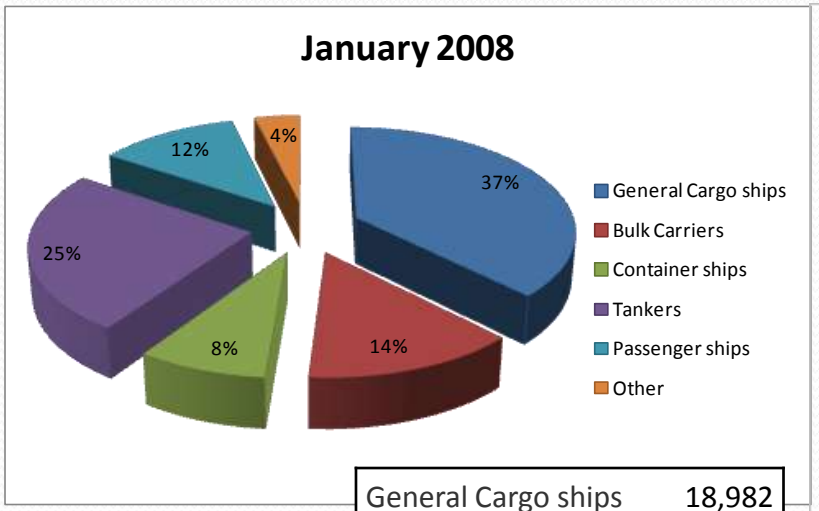
- Shore-power or "cold-ironing" enables ships at dock or in dry dock, to use shore-side electricity source to power
  - electronic systems including fuel systems;
  - loading and unloading activities;
  - and to discontinue the use of its auxiliary engines.
- This switchover of electricity source eliminates air emissions associated with the use of auxiliary engines and shifts the burden to power generation facilities in the local grid.
- Shore electric facilities have diversified energy generation sources, having regulated emission controls.

Supporting Data

Information from Shipping Trade sources
& case examples of currently trading ships.

Number of ships Globally

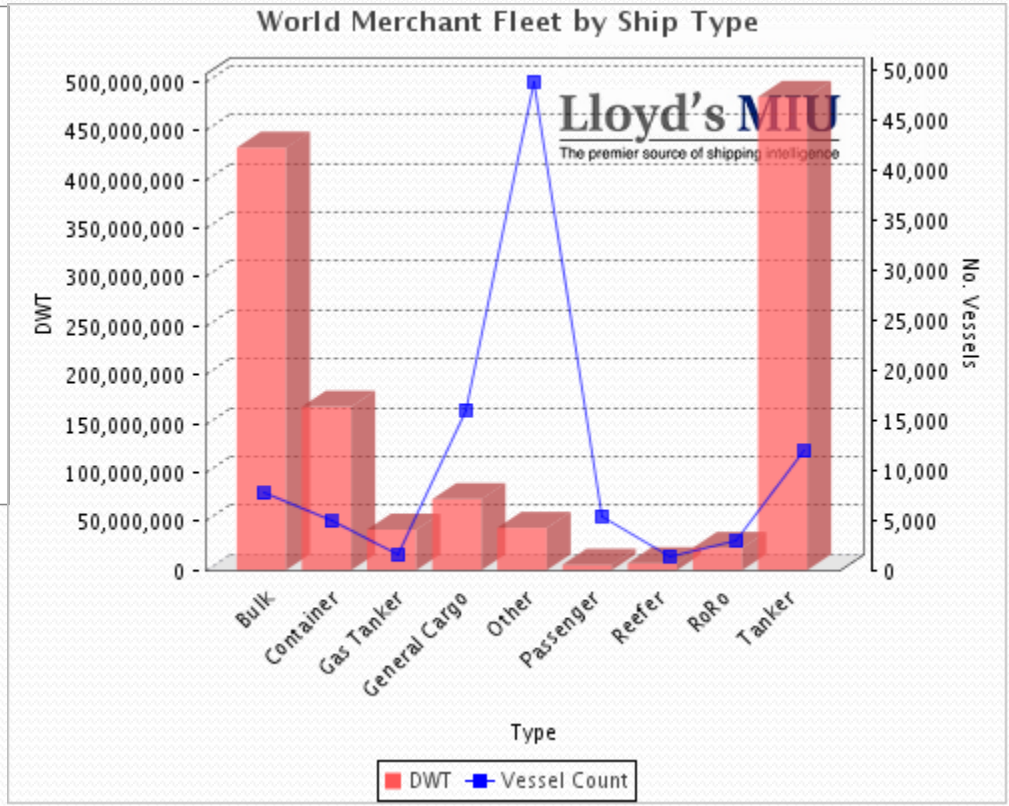
- As of 1st January 2008, the world trading fleet was 50,525 ships, with a combined tonnage of 728,225,000 gross tonnes.



General Cargo ships	18,982
Bulk Carriers	6,890
Container ships	4,170
Tankers	12,583
Passenger ships	5,957
Other	1,943
TOTAL SHIPS	**50,525**

Source: Lloyd's Register Fairplay
January 2008, >1000GT

Ships > 100GRT = 170,000 ships

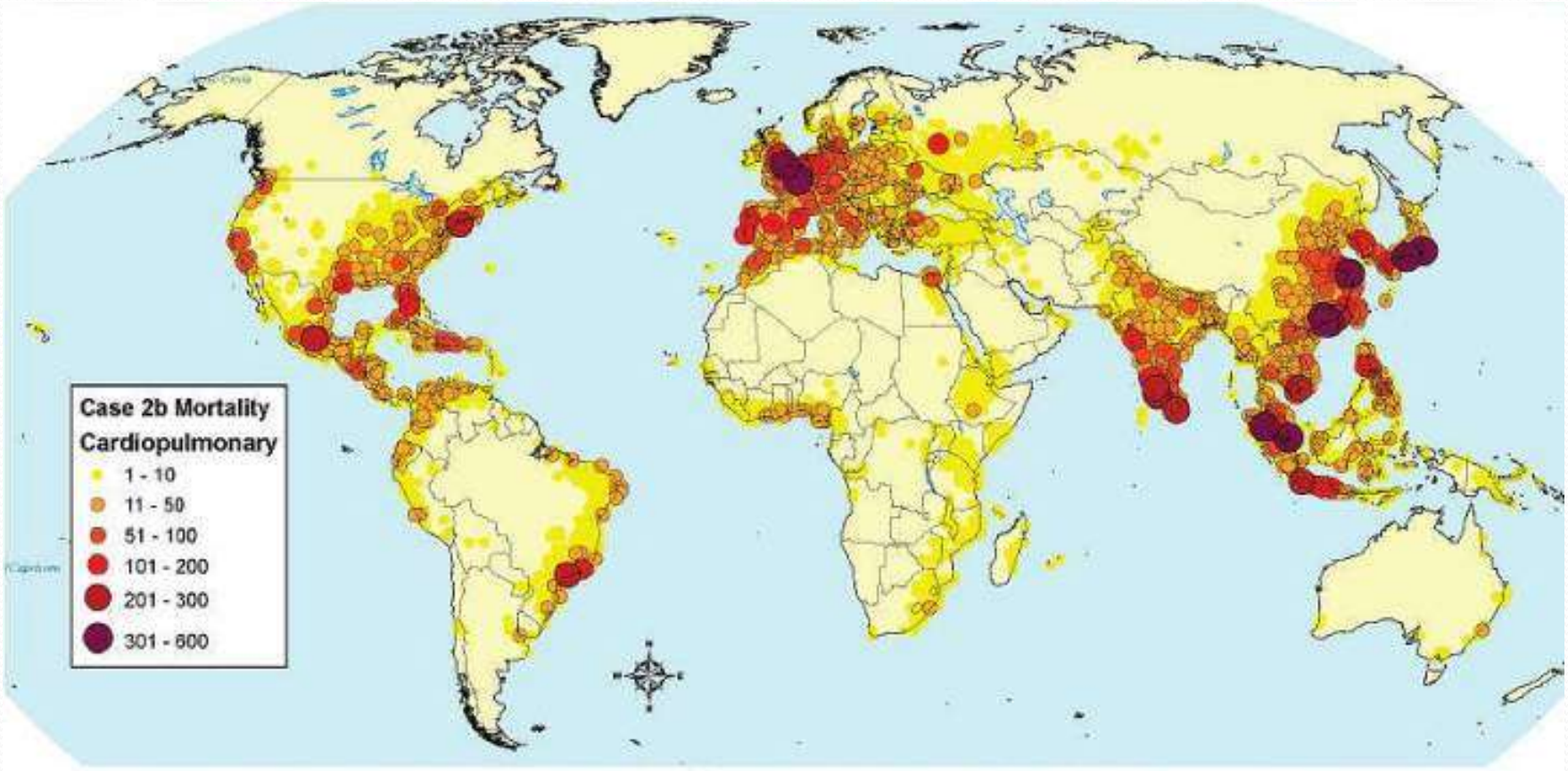


List of Ship Types

2007 Data

Ship Type	Number	Average DWT	Average Main Engine (HP)	AUX Bunker Cons (kW) per annum	Assessed Total HFO Cons. Tonnes	CO2 from Bunker cons. Tonnes (10^6)	Total SOx emission from Bunker cons. Tonnes	Total NOx Emission from Bunker cons. Tonnes	PM10 emission Tonnes
Bulk Carriers	7,002.00	52,367.00	10,367.00	96,79,565.00	5,19,36,915.00	168.81	28,77,541.00	41,53,828.00	3,33,691.00
Chem Oil tankers	1,649.00	21,031.00	7,433.00	22,79,578.00	91,56,778.00	30.47	5,11,904.00	7,43,346.00	60,138.00
Chemical tankers	1,195.00	8,328.00	4,120.00	14,91,360.00	48,06,625.00	16.36	2,71,066.00	3,95,860.00	32,240.00
Combination Carriers	110.00	53,608.00	9,395.00	1,52,064.00	7,47,965.00	2.45	41,542.00	60,064.00	4,834.00
Container carriers	3,991.00	32,896.00	28,234.00	38,31,360.00	10,25,51,791.00	314.47	55,59,774.00	79,08,519.00	6,24,046.00
Crude tanker	1,945.00	1,43,533.00	19,415.00	26,88,768.00	4,27,00,898.00	132.29	23,23,733.00	33,13,973.00	2,62,336.00
General cargo ship	13,632.00	5,498.00	3,186.00	65,43,360.00	2,04,90,663.00	82.74	12,39,732.00	18,89,895.00	1,61,467.00
Gas Tankers - LNG	375.00	74,117.00	36,175.00	69,120.00	1,56,75,000.00	47.56	8,46,512.00	12,00,888.00	94,444.00
Gas Tankers - LPG	1,061.00	14,497.00	6,152.00	14,66,726.00	60,65,143.00	20.13	3,38,723.00	4,91,538.00	39,735.00
Miscellaneous	11,902.00	1,417.00	3,199.00	57,12,960.00	64,53,645.00	54.55	5,74,856.00	10,38,473.00	1,03,490.00
Offshore vessels	4,326.00	2,473.00	5,788.00	41,52,960.00	1,24,37,179.00	73.37	9,02,332.00	15,07,317.00	1,40,781.00
Passenger/Ferry	3,759.00	1,646.00	11,526.00	51,96,442.00	2,72,19,205.00	120.49	17,15,315.00	26,75,118.00	2,34,039.00
Product tanker	2,926.00	16,754.00	5,455.00	40,44,902.00	2,31,03,134.00	74.77	12,77,935.00	18,42,742.00	1,47,841.00
Reefers Ships	2,132.00	4,175.00	5,790.00	44,20,915.00	1,04,97,832.00	37.16	6,01,312.00	8,86,916.00	73,067.00
RoRo Vessels	2,131.00	8,944.00	9,994.00	20,45,760.00	1,64,53,818.00	57.44	9,37,246.00	13,77,558.00	1,13,031.00
Tanker unspecified	1,723.00	9,070.00	3,071.00	8,27,040.00	21,77,679.00	12.79	1,57,594.00	2,62,964.00	24,536.00
Grand Total	**59,859.00**	**17,911.00**	**7,608.00**	**5,46,02,880.00**	**35,24,74,269.00**	**1,245.84**	**2,01,77,117.00**	**2,97,48,997.00**	**24,49,716.00**
		Tons	HP	(kW)	Tonnes	Tonnes (10^6)	Tonnes	Tonnes	Tonnes

Mortality due to ship emissions



Cardiopulmonary mortality attributable to ship $PM_{2.5}$ emissions worldwide, Case 2b.

Port Traffic - India

Port Name	Period	Dry Bulk	Liquid Bulk	Break Bulk	Container	Total	Others #	Total
Kolkata	2007-08	37	171	285	519	1012		1012
	2006-07	27	200	237	416	880	24	904
Haldia	2007-08	745	997	122	509	2373	-	2373
	2006-07	580	791	136	457	11889	-	1889
Paradip	2007-08	1218	229	50	16	1513		1513
	2006-07	1098	217	79	11	1405	47	1452
Vishakhapatnam	2007-08	1208	659	267	212	2346		2346
	2006-07	1010	661	205	176	2052	47	2099
Ennore	2007-08	213	-	-	-	213	-	213
	2006-07	184	17	-	-	201	-	201
Chennai	2007-08	455	422	462	713	2052	-	2052
	2006-07	463	422	476	698	2059	-	2059
Tuticorin	2007-08	407	166	589	440	1602		1602
	2006-07	325	154	496	534	1509	24	1533
Cochin	2007-08	35	350	72	349	806		806
	2006-07	54	383	92	383	912	264	1176
New Mangalore	2007-08	403	639	38	64	1144		1144
	2006-07	276	640	51	48	1015	24	1039
Mormugao	2007-08	217	175	14	37	443	-	443
	2006-07	478	161	21	39	699	-	699
Mumbai	2007-08	31	927	739	12	1709		1709
	2006-07	234	970	749	133	2086	150	2236
J.N.P.T.*	2007-08	49	312	10	2735(*)	3106	-	3106
	2006-07	46	321	14	2394	2775	-	2775
Kandla	2007-08	598	1208	557	235	2598	-	2598
	2006-07	461	906	505	252	2124	-	2124
All Ports India	**2007-08**	**5718**	**6226**	**3185**	**5831**	**20876**		**20876**
	2006-07	**5389**	**6153**	**3137**	**5605**	**20284**	**580**	**20864**

20864 ships in 13 major ports: 233 berths, 3 SBMs, 2 BJs

Bunker Costs in Port

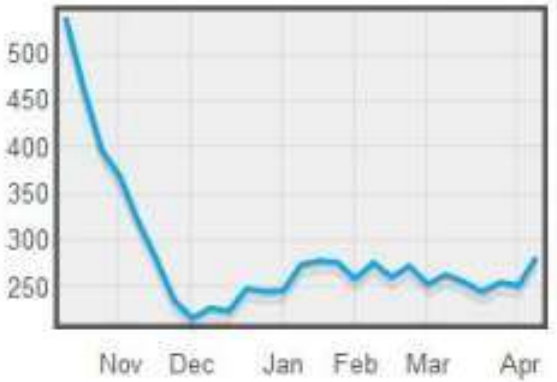
CASE 1 : MV ------, one of world's largest Reefer Container Ship

- In a voyage of 21 days-

Port Stay	Hours	Days	AE Cons. MT
Port 1	8.00	0.33	6.67
Port 2	48.00	2.00	43.00
Port 3	6.00	0.25	5.00
Port 4	48.00	2.00	35.00
Totals		4.58	89.67

- In a year, 76 days in port, 1460 MT fuel.
- Average 19.5 MT per day in port-
  - 2009 Q1: x USD 263 = USD 5,128/-
  - 2008 Q3: x USD 678 = USD 13,221/-

Bunker FO Prices in USD



Quarter	Average $/MT
Q1 2009	263.00
Q4 2008	309.00
Q3 2008	678.50
Q2 2008	601.50
Q1 2008	495.00
Q4 2007	479.50
Q3 2007	388.00
Q2 2007	361.00

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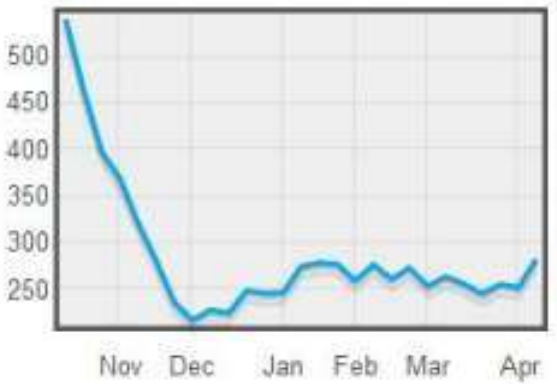
Bunker Costs in Port

CASE 2 : MV ----, Typical General Cargo cum Reefer Ship

- In 365 days, spent-
  - 117 days in port
  - 675 MT of bunker fuel for power

- Average 5.77 MT per day in port-
  - 2009 Q1: x USD 263 = USD 1,517/-
  - 2008 Q3: x USD 678 = USD 3,911/-

Bunker FO Prices in USD



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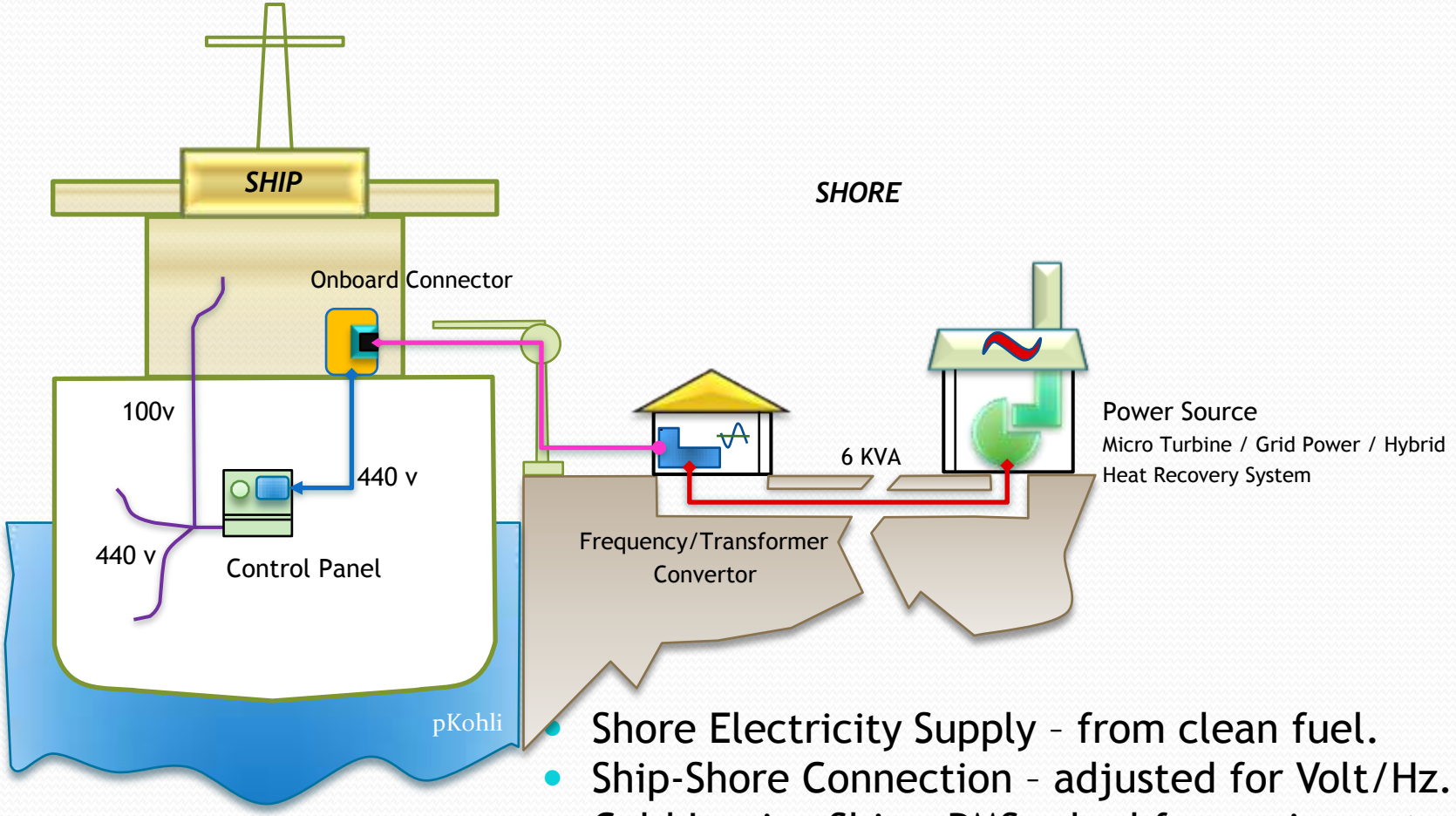
Proposed "Cold Ironing"



- Shore Electricity Supply – from clean fuel.
- Ship-Shore Connection – adjusted for Volt/Hz.
- Cold Ironing Ship – PMS sched for equipment.
- 1 hour to connect, 30 minutes to disconnect.

Load Requirement in Port

CASE 1:
Operating Voltage: AC 440V / 220V
Automation System: Gavazzi, Sulzer – operates on AC220V / DC24V
Diesel Generators: Bergen Diesel KRG 7590KW - 2 x 1430KW; 3 x 1260KW; 1 x 950KW

Emergency Generator – Essential Services backup	110 KW
Shore Connection Max Capacity of CB	315 Amps at 195 KW
Lighting - Internal	70 KW
Accommodation/Control Room Air Conditioners	112 KW
Provision Room Compressors	12 KW
Essential Services (SW/LT/CW Pumps, Boiler)	410 KW
Purifiers – HFO, LO	23 KW
Emergency Service (Fire Pumps)	26 KW
Bilge pump	26 KW
Ballast Pumps (transfer & pump in ballast) x 2nos	37 KW
Machinery Space Ventilation	105 KW
Cargo Hold Ventilation	20 KW
Galley Services	25 KW
Mooring Winches each (x 4 nos)	50 KW
Container Operating Load (cycling 60% load)	2400 KW
Ship's Cargo Gantries	850 KW
Anti-Heeling pumps – each (x 2 nos)	105 KW
Main / Service Air compressors	110 KW
Bow Thruster (emergency use)	670 KW
Steering gear (pre-sailing test)	37 KW

Typical Fleet Consumptions

PERFORMANCE ANNUAL ANALYSIS

Actual Fleet Indicator Data

SHIP NAME	DAYS					LOADED				BALLAST			
	SEA	PORT	D/D	OFF HIRE	TTL	MILES	SPD (Knots)	Tons per Day Main	Tons per Day Aux.	MILES	SPD (Knots)	Tons per Day Main	Tons per Day Aux.
GRAND LADY	179.6	68.2	24.4	92.8	365	38,772	18.09	38.97	6.07	39,433	18.21	36.19	2.96
SISTER 1	287.8	76.3	-	0.9	365	62,901	17.83	25.69	6.84	63,317	18.73	25.34	2.95
SISTER 2	283.0	80.9		1.2	365	62,747	18.21	25.67	7.56	59,680	17.85	22.90	2.81
SISTER 3	234.3	130.5	-	0.2	365	54,600	18.02	26.33	7.54	49,604	19.13	26.29	3.06
SISTER 4	226.0	122.0	17.0		365	50,439	17.61	28.02	7.41	40,509	17.30	24.69	2.90
FANCY 1	287.0	77.0	1.0		365	70,933	19.97	39.60	9.19	65,685	19.69	35.71	3.97
FANCY 2	290.1	75.0		-	365	70,013	19.61	40.25	9.27	65,488	19.34	37.72	3.61
FANCY 3	290.1	75.0			365	70,458	19.91	40.36	9.29	65,882	19.35	36.05	3.76
FANCY 4	286.5	78.5			365	68,743	19.98	41.61	9.20	67,770	19.73	35.74	3.60
ELDER 1	241.5	107.5	16.0		365	56,168	19.07	39.23	14.56	52,998	18.61	37.09	6.14
ELDER 2	242.1	109.7	13.1	0.1	365	56,691	18.96	45.95	14.54	52,639	18.66	47.99	4.82
ELDER 3	270.0	80.0	15.0	-	365	59,756	17.84	41.69	19.16	58,467	18.72	40.61	4.20
ELDER 4	267.0	83.0	15.0	-	365	58,771	18.25	42.73	19.66	60,879	19.08	41.07	4.72
BIG 1	239.0	126.0	-	-	365	66,838	20.76	70.40	25.34	50,407	20.05	70.84	8.62
BIG 2	235.0	117.0		13.0	365	62,960	20.04	62.66	25.11	48,644	19.45	62.71	8.21

Latest Bunker Prices

Bunker Prices – Apr 2009

Ports	HFO 380cst U$ / MT	HFO 180cst U$ / MT	MDO U$ / MT	MGO U$ / MT
Singapore	310.00	320.00	441.00	462.00
Houston	288.00	302.50	470.00	
Rotterdam	280.50	306.50	422.00	463.50
Fujairah	301.50	317.50		518.50
Average Price	USD 302	USD 312	USD 444	USD 481
Cost @ 5 MT/day	USD 1,507.50	USD 1,558.13	USD 2,221.67	USD 2,406.67

- *For every kilowatt-hour (kWh) electricity, about 200 grams of bunker fuel is used. This means a bunker oil usage of as much as 0.55 tonnes every hour. For 1 kilo of bunker oil =3.125 kilos of Carbon dioxide.*

Type of Marine Vessels & Average Power Requirement at Berth	
Container Ships	1 - 4 MWe
Cruise Ships	7 MWe
Reefers	2 - 5 MWe
Ro-Ros	700 kWe
Tankers	5-6 MWe
Bulk/Cargo Ships	300 kWe-1 MWe

Case for Business

- Cheaper and reliable source of energy while ship at ports- Ship's Cost:
  - Fuel Costs (fluctuating and new regulations demand more expensive fuel be used).
  - Segregated Fuel Storage – HFO for sailing and MGO in port. Fuel Stored detracts from Cargo capacity.
  - Maintenance Costs – sustained running hours and PMS monitoring by PSC adds to manpower & spares costs.
  - Compliance Costs, energy costs.

Case Study - Cost of Generation

Compilation of calculated results from Case studies by **MariTerm AB**

Operator:	DFDS Tor Line	Stena Line	Cobelfret	ACL	P&O	Superfast Ferries	
Service between:	*GOTHENBURG - IMMINGHAM*	*GOTHENBURG - KIEL*	*GOTHENBURG - ZEEBRUGGE*	*GOTHENBURG - LIVERPOOL - ANTWERP - BREMERHAVEN*	*ROTTERDAM - HULL*	*ROSYTH - ZEEBRUGGE*	
Vessels:	*TOR BRITANNIA, TOR SELANDIA, TOR SUECIA*	*STENA GERMANICA, STENA SCANDINAVICA*	*SLINGEBORG, SCHIEBORG, SPAARNEBORG*	*"ATLANTIC " CONCERT, CONVEYOR, COMPANION, COMPASS, CARTIER*	*NORSEA, NORSUN, PRIDE OF ROTTERDAM, PRIDE OF HULL*	*Supefast IX, Superfast X*	
Energy consumed at quay	6122484	7329024	1230883	5387200	20926180	5219500	kWh
Fuel Consumed Total	1393	1691	300	1137	4323	1070	MT
Fuel Consumed per KWh	0.228	0.231	0.244	0.211	0.207	0.205	Kgs/kWh
Onboard generated power HFO	426341	517420	91846	347832	1322698	327363	USD
Cost per KWh	0.070	0.071	0.075	0.065	0.063	0.063	USD/kWh
Onboard generated power MGO	645085	782893	138969	526295	2001337	495324	USD
Cost per KWh	0.105	0.107	0.113	0.098	0.096	0.095	USD/kWh

- Shows direct costs are comparable.
- Indirect costs : maintenance, cost of bunkering, displacement loss, energy demand differential, cost of pollution and compliance.

Practical Issues

To implement Shoreside electrification

Concerns

- Cost of Infrastructure-
  - Power source.
  - Power Cables and cable handling system.
  - Switchgear, transformers, convertors.
- Compatibility – voltage and frequency.
- Safety standards in compliance with international maritime norms.
- Quality of power to protect shipboard automation systems.
- Legalities with various stakeholders.

Varied Requirements

- Most ships operate on low voltage 440 V electrical power, while large container and cruise ships operate on high voltages of 6.6 to 11 KV.
- Frequency requirements also vary depending of place of construction of ship (50 or 60 Hz).
- Power convertors will be required either on board the ship or at the terminal to provide electricity.

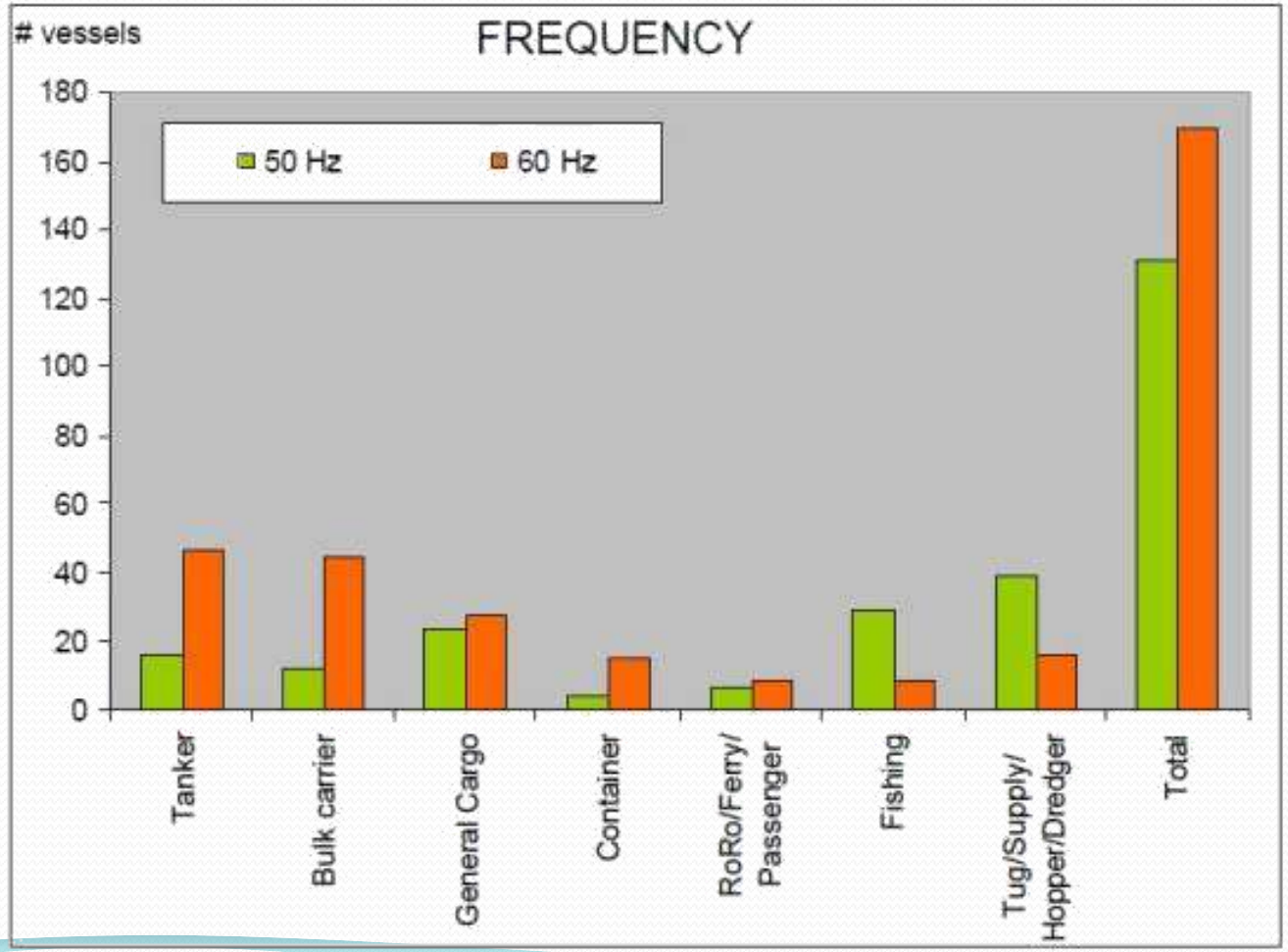
  - To retrofit a ship, the estimated cost is between $200,000 to $574,0000.
  - Shore-side costs vary from place to place and depends on availability of shore power.

- Power load requirements vary from 1 to 4 Megawatts for a container ship to 5 to 10 Megawatts for a cruise ship.

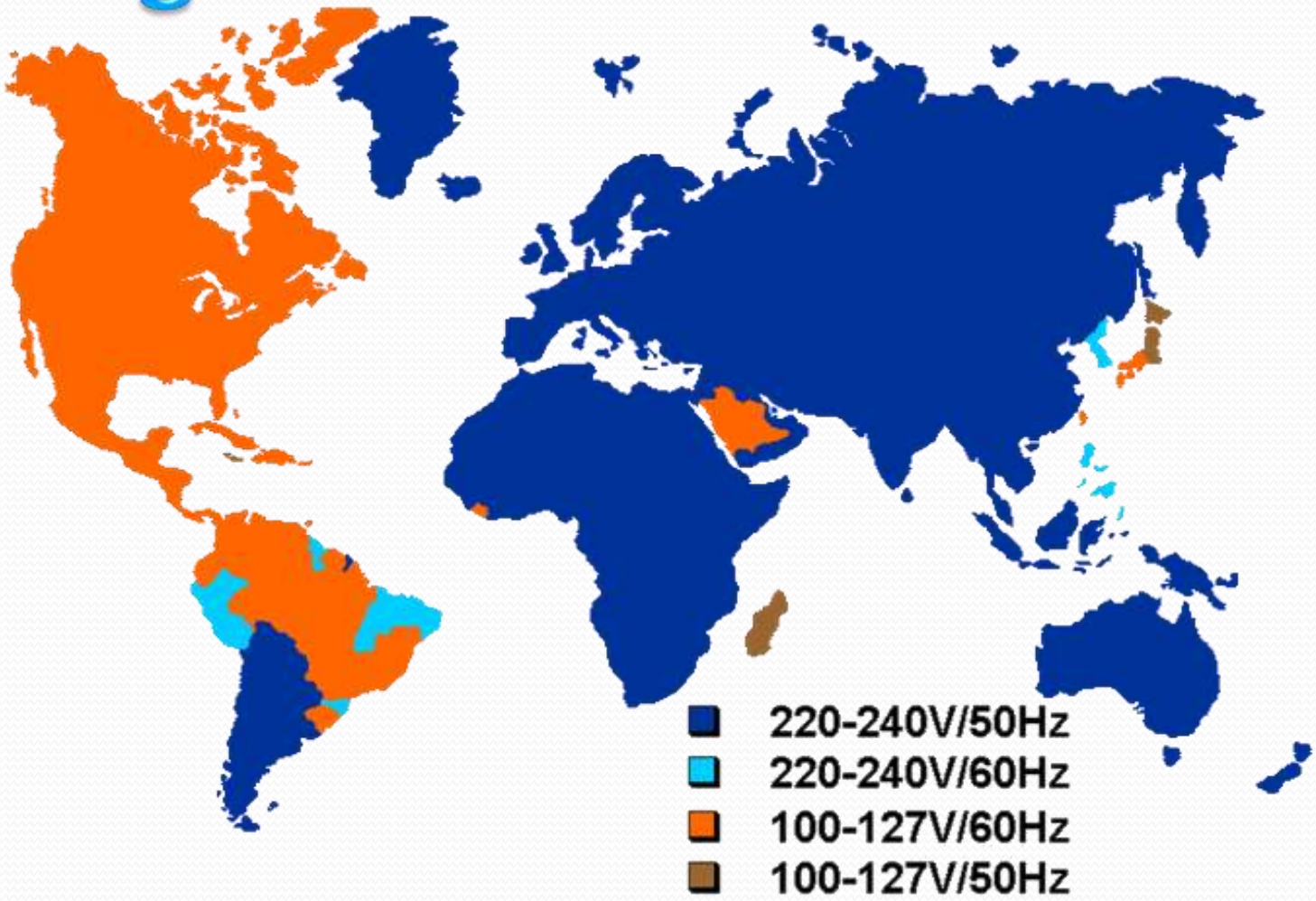
Ocean going vessels fall into two categories, low-voltage and high-voltage. Except for passenger ships, high voltage is nominally 6.6kV and low-voltage is around 440V. For passenger ships, high voltage is 11.0V, while low-voltage is 6.6V.

Frequency Used

Frequency used onboard different vessel types (300 random vessels from Lloyd's Register - Fairplay, 2002)



Voltages used



Ships tend to have requirements depending or location of building yard.

Cable Standards, Management

- Connectors to Ships' Bus Bar – Electric Control Panel vary – standards under ratification.

Competition/Support

- Companies working towards cold-ironing:
  - Seimens
  - TEMCO
  - Cavotec
  - Wittmar (CleanAir Marine Power)
  - Cochran
- Strong support for cold-ironing-
  - Tax exemptions.
  - Emission trading.
  - Interest from shipping companies.
  - Reduced energy load with on board systems ‘cold’.
  - Oil prices expected to rise 30% to 50%.

Pollution Data

Maritime Pollution

From Power generation

Pollution Data

- Shipping industry emits almost twice the CO2 levels the aviation sector produces and over 200 times the harmful Sulphur Oxide (SOx) emissions of all the cars in the world – equivalent to 195 billion cars. In effect, one ship produces the same amount of SOx as 50 million cars.
- IMO task force concluded shipping emission levels are currently as high as 1.1 billion tonnes of CO2 and over 16 million tonnes of SOx – and rising fast.
- One 12,000 TEU containership ship burns 350 metric tonnes of heavy fuel oil (bunker fuel) at 2.7% sulphur content (global average, IMO), producing 19 tonnes of Sulphur Oxide (SOx) per day. If this ship operates for 300 days per year, total SOx emissions stand at 5,700 tonnes per year. Approx 35 million cars in the UK, burn an average of 118 grams of sulphur per year (basis on 10,000 miles per year), equivalent to 4,130 tonnes per year. *Source: *SustainableShipping.com*

Pollution

Heavy Fuel Oil	NOX [kg/ton fuel]	SO2 [kg/ton fuel]	CO2 [kg/ton fuel]	CO [kg/ton fuel]	VOC [kg/ton fuel]	PM [kg/ton fuel]	PAH [kg/ton fuel]	
Auxiliary Engine E	70	44	3 199	4,17	0,79	3,10	50,93	Residual Oil
Auxiliary Engine F	59	44	3 212	3,55	0,88	2,49	43,78	Residual Oil
Average HFO	65	44	3 206	3,86	0,83	2,80	47,35	

2,2% % S"

Marine Gas Oil	NOX [kg/ton fuel]	SO2 [kg/ton fuel]	CO2 [kg/ton fuel]	CO [kg/ton fuel]	VOC [kg/ton fuel]	PM [kg/ton fuel]	PAH [kg/ton fuel]	
Auxiliary Engine G	83		3 159	3,32	1,38	0,70	6,54	MGO
Auxiliary Engine A	80		3 189	3,63	0,78	1,56	-	MGO
Auxiliary Engine C	75		3 175	2,05	1,00	1,69	0,77	MGO
MGO	79	4	3 174	3,00	1,05	1,31	2,44	

- Vessels use auxiliary engines to produce onboard electricity while at the dock to power lighting, ventilation, pumps, air conditioning, refrigeration and other on-board amenities as well as systems for cargo & safety operations.
- These “hotelling” emissions can comprise as much as 20 percent of all particulate matter (PM) emissions from a large port city.
- At the Ports of Los Angeles and Long Beach – the third busiest port complex in the world after Hong Kong and Singapore - ships produce 343 tons per year of cancer-causing particulate matter every year.
- Equipping ships and ports for shoreside power capabilities can be a cost effective air pollution reduction mechanism particularly for container, cruise and reefer vessels that call regularly at the same port.
- Estimated costs are $4 to $13 per TEU for container ships or $12 to $16 per passenger on cruise ships (USA costs, LA Study).

Pollution

- Commercial vessels monitor their fuel consumption
  - Through mechanical or electronic flow meters.
  - By regularly monitoring calibration tanks.
  - Bunker delivery notes may serve as verification.

… maritime transport will be included in any future discussions on global emerging concerns such as security, air pollution and climate change.

Shipping companies are increasingly incorporating a “triple bottom line” approach in their reporting by quantifying & reporting environmental and human impacts alongside profits.

  - Onus on bunker companies to certify fuel quality.
  - Counter checks through lab analysis - mandatory.

Other Energy Saving Options

Maritime Energy Needs

Explored in last few years

Other energy Savers

- Wind Energy – Sky Sails – using high altitude apara sails on motor ships.
- Fuel Cell powered passenger ferry on 29-Aug-08 (Hamburg).
- Hull design - Compress Air technology to alleviate friction losses.
- Special self polishing Hull paints – reduce barnacle buildup and streamline water flow.
- Wind Turbines – High Atmospheric – helium based high altitude wind turbines for electricity.

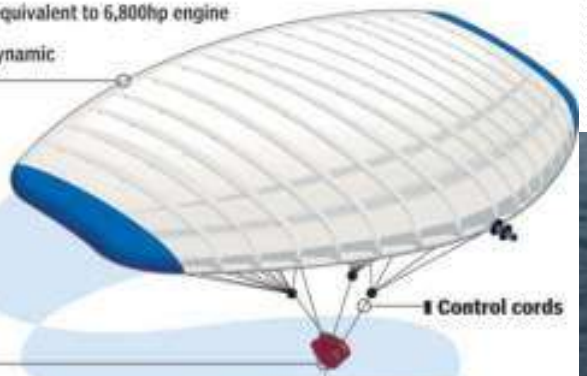
GIANT KITE WILL PULL SHIP ACROSS ATLANTIC

The world's first commercial cargo ship powered partially by a kite is making its maiden voyage from Germany to Venezuela. The designers of the computer-guided kite say it could cut fuel consumption by as much as 20% and help reduce carbon dioxide emissions

SkySails: Largest kites have towing power equivalent to 6,800hp engine

Parafoil: 160-5,000m² multi-cell kite – aerodynamic shape generates lift for greater traction

Cross-section



Control cords

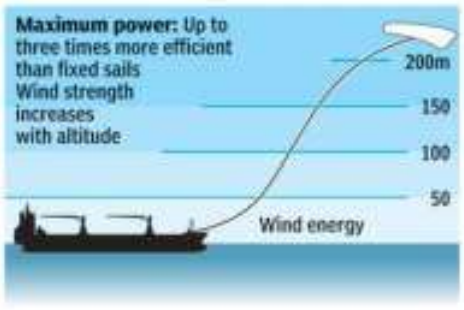
Control pod: Automatically aligns kite – based on wind direction, force, ship route and speed – by pulling control cords

MS Beluga SkySails: 10,000 tonnes

Tow rope: Low-weight, high-strength carbon fibre

Sailing direction: SkySail can be used to sail at up to 50° against wind

Maximum power: Up to three times more efficient than fixed sails
Wind strength increases with altitude



Stability: Lift force minimizes heeling of ship

SOURCES: SKYSAILS, BELUGA GROUP, WINTECC PROJECT

GRAPHIC NEWS / NATIONAL POST

Fuel Cell

Wärtsilä Technical Report(2008)
For ships

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Thank You