Effects of the Energy Efficiency Design Index on the Marine Transportation System

William A. Hockberger
Consultant
Marine Systems Planning, Design, Development

TRB Conference
Diagnosing the Marine Transportation System
26-28 June 2012

Outline

- Background
- What EEDI is
- Planned application
- Energy-reducing technologies
- Ship speed/power reduction
- Effective prohibition of high-speed ships
- Need for total-system, long-term evaluation on an economic basis
- Conclusions

Background

- Previous/continuing ship emission reductions
- Now CO_2 – starting 1 Jan 2013
- Work of MEPC of IMO
- SEEMP: operational measures
  - Plan required but actions voluntary
- EEDI: design/technical measures
  - Mandatory, close oversight & control
- MBM: market-based measures

EEDI calculation

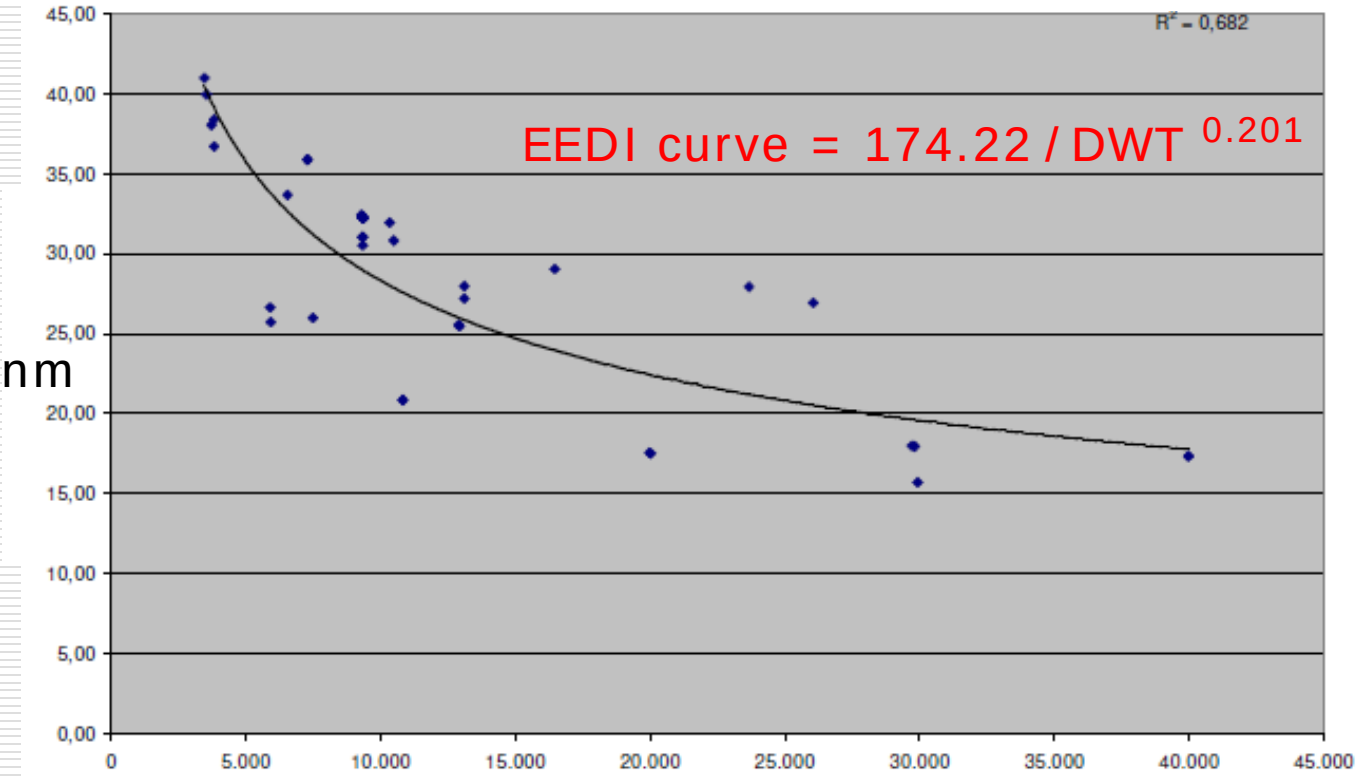
$$EEDI = \frac{CO_2 \text{ emissions}}{\text{capacity x distance}}$$

$$\frac{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right) + \left(\left(\prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}**\right)}{f_i \cdot f_c \cdot Capacity \cdot f_w \cdot V_{ref}}$$

$$Estimated\ Index\ Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{NME} P_{MEi} + 215 \cdot P_{AE}}{Capacity \cdot V_{ref}}$$

Development of EEDI points & curves

Containerships: $$Estimated\ Index\ Value = 3.1144 \cdot \frac{190 \cdot \sum_{i=1}^{NME} P_{MEi} + 215 \cdot P_{AE}}{70\%\mathrm{DWT} \cdot V_{ref}}$$



EEDI reduction factors

Table 1. Reduction factors (in percentage) for the EEDI relative to the EEDI Reference line

(from MEPC 62/24/Add.1 Annex 19)

Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Bulk carrier	20,000 DWT and above	0	10	20	30
	10,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Gas carrier	10,000 DWT and above	0	10	20	30
	2,000 – 10,000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Container ship	15,000 DWT and above	0	10	20	30
	10,000 – 15,000 DWT	n/a	0-10*	0-20*	0-30*
General Cargo ships	15,000 DWT and above	0	10	15	30
	3,000 – 15,000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	5,000 DWT and above	0	10	15	30
	3,000 – 5,000 DWT	n/a	0-10*	0-15*	0-30*
Combination carrier	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*

Ro-Ro, Ro-Pax, passenger TBD for 2015 Phase 1

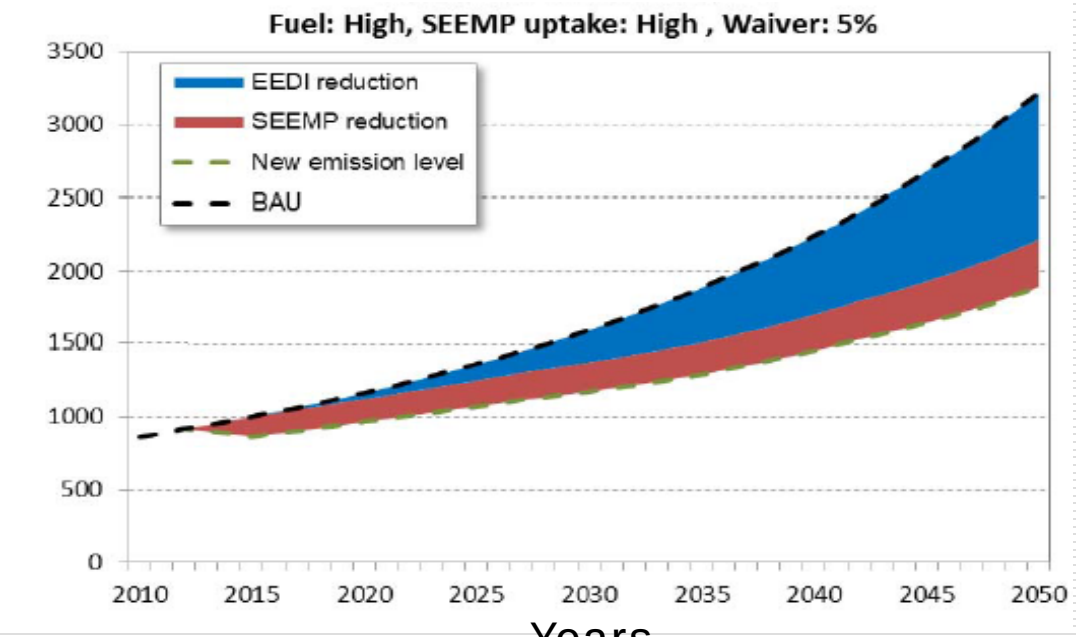
Service, offshore, fishing, etc. types intended but still undetermined

Eventually every ship & boat type will be included

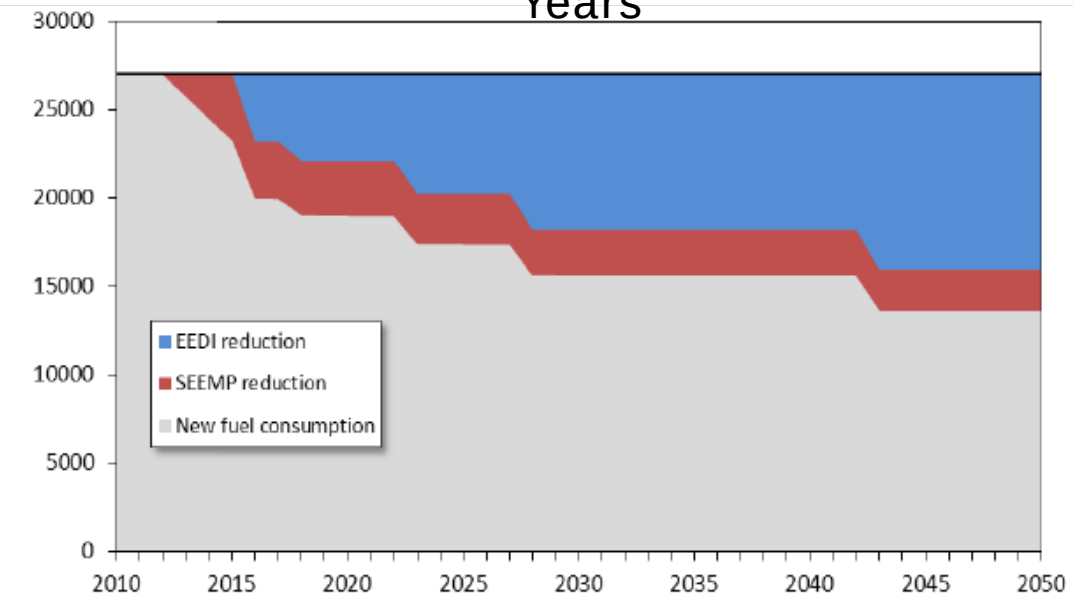
It is expected that a Phase 4 will begin in 2040 with a 40% reduction

Estimated reductions in CO_2 & fuel

Annual CO_2 of world fleet, million tonnes



Annual fuel consumption, 5500 teu containership, tonnes



EEDI & SEEMP measures

	EEDI reduction measure	SEEMP Related measure
1	Optimised hull dimensions and form	Engine tuning and monitoring
2	Lightweight construction	Hull condition
3	Hull coating	Propeller condition
4	Hull air lubrication system	Reduced auxiliary power
5	Optimisation of propeller-hull interface and flow devices	Speed reduction (operation)
6	Contra-rotating propeller	Trim/draft
7	Engine efficiency improvement	Voyage execution
8	Waste heat recovery	Weather routing
9	Gas fuelled (LNG)	Advanced hull coating
10	Hybrid electric power and propulsion concepts	Propeller upgrade and aft body flow devices
11	Reducing onboard power demand (auxiliary system and hotel loads).	
12	Variable speed drive for pumps, fans, etc.	
13	Wind power (sail, wind engine, etc.)	
14	Solar power	
15	Design speed reduction (new builds)	

Energy-reducing technologies

- EEDI will push assessment of new ones
- Many concepts, but few work well
- Owners consider carefully before accepting
  - Effectiveness varies with application
  - Must balance benefits vs. costs
- Most already used if effective & economical
  - Long ship replacement cycle
  - Low fuel cost last time

Effects of adding an item of equipment

- The item itself
- Support from the ship
  - Space, accessibility
  - Structural support, mounting/isolation
  - Electric power, cooling, ventilation
  - Control signals, data
  - Protection from EMI, heat, fire
  - Ongoing operation, maintenance, repair
  - Ongoing logistic support
  - Buoyancy to carry added weight
  - Increased ship power & fuel
- Negative effects to be contained
  - Heat, noise, vibration, EMI
  - Waste, effluent, pollution, odors

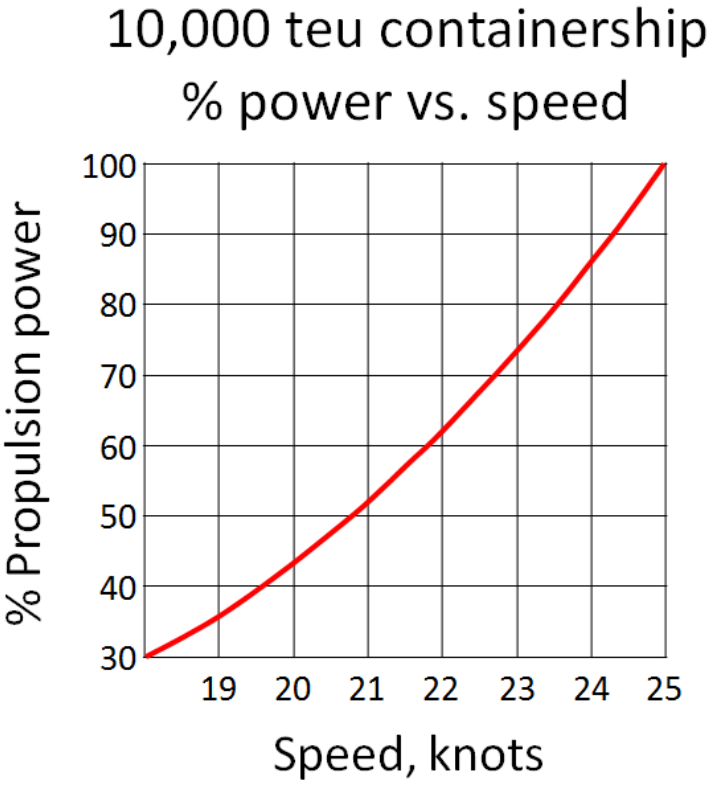
These generate a compounding effect that increases the final amounts.

Each also has costs that must be paid.

Owners can't afford to install equipment that won't pay its way.

Speed/power reduction

- Greatest scope for energy/CO_2 reduction
  - Business trade-off against new energy-reducing technologies
  - Predominant in later EEDI stages
- Present speeds would have been made lower if present fuel costs expected
- Major issues about speed in EEDI
  - Some smaller ships advantaged over large
  - Reference speeds set for a single nontypical point
  - Ro-Ro, Ro-Pax, etc., require speed
  - “Middle market” for large fast ships essentially prohibited



Speed reduction consequences 1

- Longer voyage times
  - More days' expenses at sea
  - Lower productivity per ship
  - Less shipping of time-sensitive products
  - More product inventory at sea
  - Less on-time service, less-predictable service
  - Safety issues re maneuvering and in heavy seas
  - Increased vulnerability to pirates
  - Loss of customers to air, rail, highways

Speed reduction consequences 2

- More ships required
  - Recession slow steaming shows this
  - More personnel & facilities
  - Congested harbors, canals, straits
  - Larger ports, more pier space
  - More construction, support, repair

Speed reduction consequences 3

- Fuel & emissions
  - Reduced by:
    - Efficiency-enhancing systems
    - CO_2-reducing systems
    - Lower propulsion power
  - Increased by:
    - More ships operating for longer periods
    - Switches to air, rail, highways
    - More ship construction, heavy industry

Speed is an important element of progress & well-being

- Having things progressively sooner
- Transportation planning emphasizes time reduction
  - Improves mobility
  - Increases feasible distances
  - Increases feasible markets
- Containership speed has risen over time
  - Slow steaming has obscured the trend
  - Higher speed bought as economical & necessary
  - Full speeds will be resumed when economy improves
- Even faster ships would naturally come along as people found needs for them

High-speed ships now operating

Leonora Christina 113m

Denmark	
Faergen	
246	
Catamaran	
113.00 metres	
1400 passengers and 357 cars	
up to 40 knots	
May 2011	
No	
4 x MAN 20V28/33D 9,100 kW	

Benchijigua Express 127m

Spain	
Fred. Olsen S.A.	
260	
Trimaran	
126.70 metres	
1350 pax 341 cars	
40.5 knots	
Apr 2005	
No	
340 cars or 450 truck lane metres and 123 cars.	

Stena Voyager 127m

Operator: Stena Line
Route: Stranraer - Belfast
Built: 1996
Builders: Finnyards, Finland
Refurbished: 2008
Gross tonnage: 19,638
Passengers: 1,500
Cars: 360
Length: 417ft
Width: 131ft
Speed: 40 knots

FastShip TG-770 semi-planing monohull

Not allowed under EEDI rules

Characteristics

- Length 870 ft
- Beam 131 ft
- Draft 33 ft
- Service speed 37 kts (25 ft waves)
- Horsepower 236,000
- Displacement 36,440 tons
- 1432 teu, 10,000 tons cargo

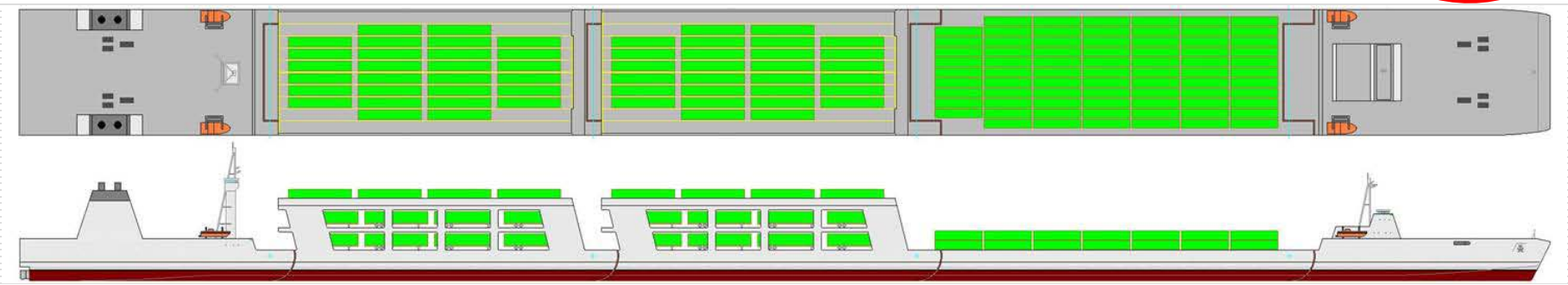
Market

- High value time-sensitive products
- Time-definite departure & delivery
- New markets, e.g. perishables
- Reduced product inventories in transit
- ¼-½ cost of air freight
- ¼-½ the time of regular containerships
- Military contingency employment

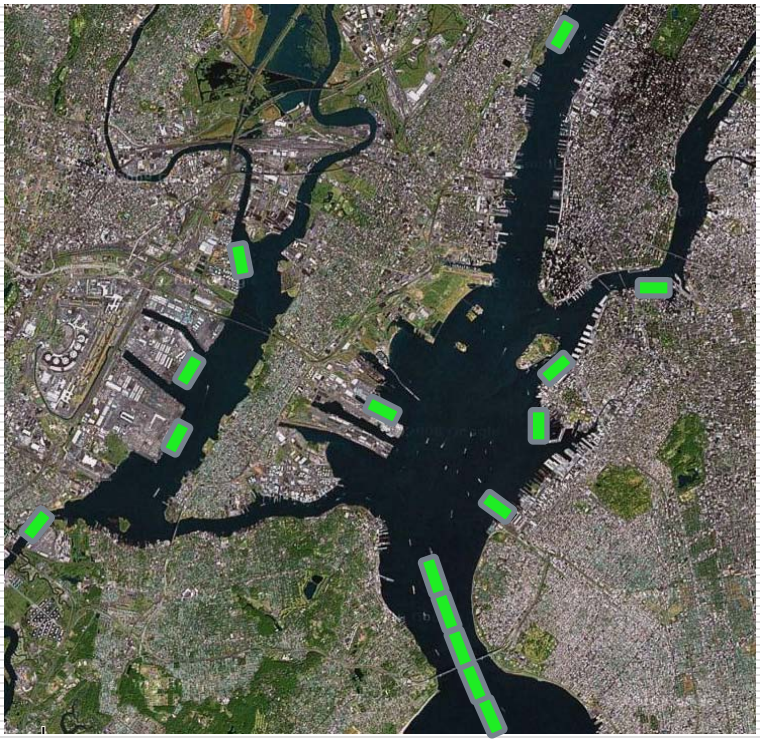
Fuel consumption and CO_2, grams per tonne-kilometer				
	747-400 air freight	FastShip (MGO)	FastShip (LNG)	Containership 5500 teu (HFO)
Fuel burn	264	75	69	12
CO_2 emissions	819	239	182	36

SeaTrain: marine analog to trains on rails

Not allowed under EEDI rules



1270 x 105 x 16 feet, 15,500 tons, 30 kts, 52,000 horsepower – 300 53-ft trailers + 150 40-ft containers



High-speed SeaTrain for:

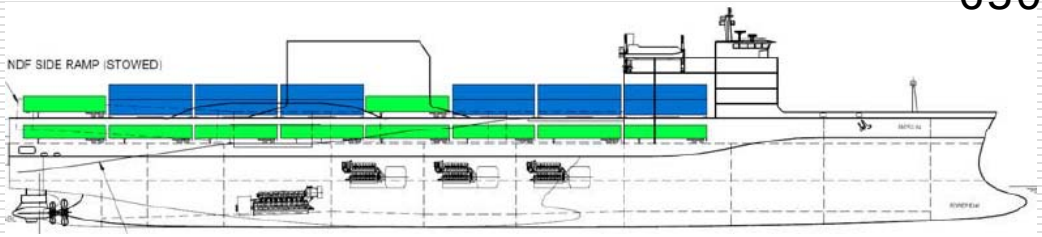
- High value time-sensitive (HVTS) goods
  - Electronics
  - Pharmaceuticals, biochemicals
  - Fruits, vegetables, cut flowers
  - Live animals and animal products
  - High-end vehicles
  - Fashion products
- Military cargoes in contingencies & wartime

- Simultaneous load/offload in multiple locations
- Different cargoes to different locations
- Rapid turnaround of costly propulsion unit
- Serve smaller facilities & waterways
- Increased reliability & survivability

Other proposed middle market ships not allowed

Nigel Gee Pentamaran –
900 ft, 40 kts, 40,000 tons

CCDoTT Trimaran
650 ft, 35 kts, 9,000 tons



CCDoTT Trimaran – 1000 ft, 29 kts, 40,000 tons

Need a balanced benefit-cost approach to EEDI

- EEDI will have huge effects not yet examined
  - EEDI = $\frac{CO_2 \text{ emissions}}{\text{capacity x distance}} = \frac{\text{society's costs}}{\text{society's benefits}}$ is too simplistic
  - Major costs, not just cost reductions
  - Important to balance against other things
    - Economic impacts
    - Quality of life aspects
  - Tough trade-offs we often make
    - Value of human life in risky work
    - Probability of car crash injuries & deaths
    - Probability of pollution from ship mishaps
    - Buildings & infrastructure vs. earthquakes & floods
  - Study the total system over the long term
    - Without EEDI
    - With various levels of EEDI
  - Balance CO_2 reduction against other objectives

We regularly make decisions knowing we can't entirely prevent or avoid disaster.

EEDI benefit-cost analysis process

- Involve all stakeholders and right experts
  - Producer & industry groups
  - Citizen & consumer groups
  - Business people
  - Government people
  - Ship owners & operators
  - Other transportation modes
  - Technical experts
  - Economists

People affected by EEDI, not just those establishing it

- Model the total system and simulate over the long term
  - Without EEDI
  - With various levels of EEDI

Including relevant unquantifiable factors as well

- Assess benefit-cost & profitability
- Balance CO_2 reduction against other societal needs & objectives

Conclusions

- EEDI starts 1-1-2013 and will build gradually over years
- SEEMPT & EEDI will reduce fuel use and CO_2 significantly
- Technical assessment process well developed
- New technologies fewer and less effective than expected
- Predominantly speed reduction for CO_2 reduction
- EEDI will have unfortunate side-effects
  - Undesirable speed reductions for ships needing speed
  - Reduced use of ships for transport
  - Wide economic effects from less ship use
  - Effective prohibition of new high-speed ship concepts for the middle market
- Total-system long-term economic assessment not conducted and badly needed

Back-ups

Carbon & CO_2 content of fuels

Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
1. Diesel/Gas Oil	ISO 8217 Grades DMX through DMC	0.875	3.206000
2. Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.86	3.151040
3. Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.85	3.114400
4. Liquified Petroleum Gas (LPG)	Propane Butane	0.819 0.827	3.000000 3.030000
5. Liquified Natural Gas (LNG)		0.75	2.750000

Transit distance, time & speed

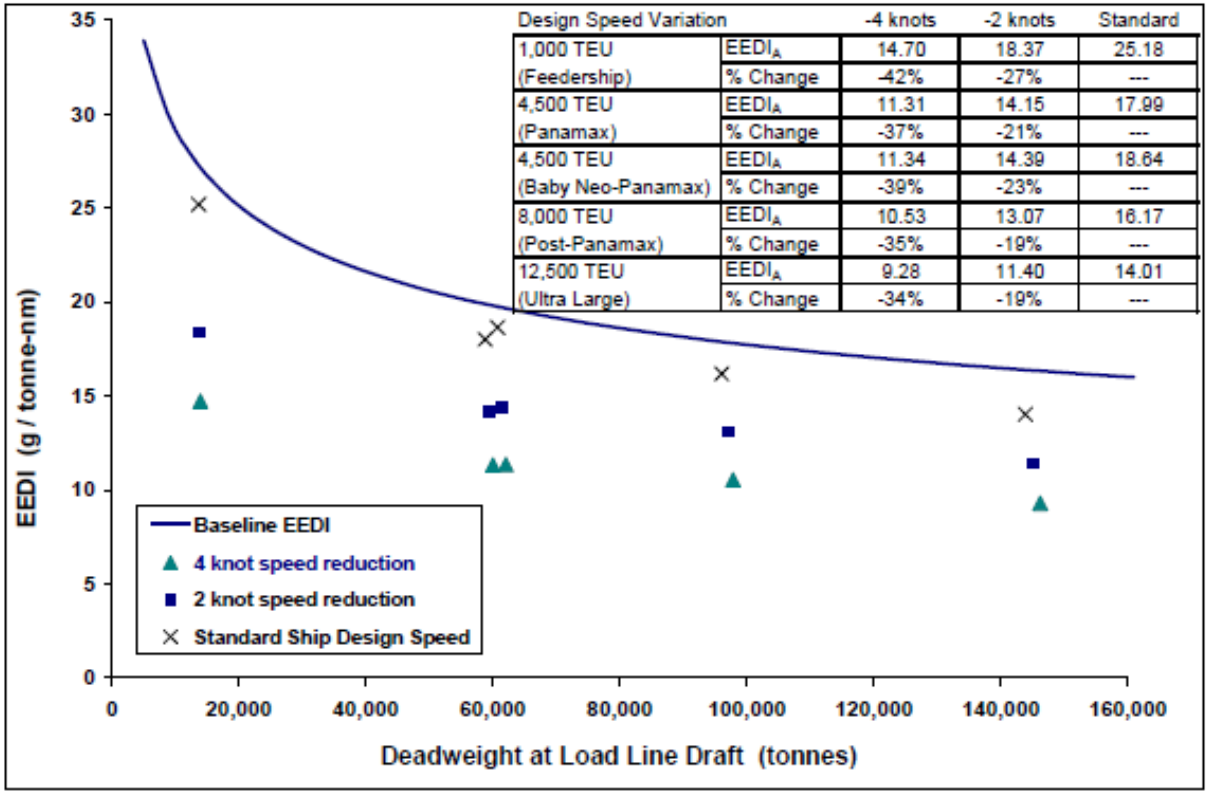
	Los Angeles	New York	Rotterdam	Hamburg	Valence
Hong Kong	6 363 12-15 22	11 207 22-32 21	9 748 19-24 21	10 001 22-29 19	8 143 17-28 20
Singapore	7 669 13-19 24	10 133 29-36* 14	8 288 15-20 23	8 541 21-22 17	6 683 13-23 21
Djakarta	7 899 17-21* 19	10 393 31-43* 14	8 548 26-29 14	8 801 25-28 15	6 943 26-31* 11
Manilla	6 533 24-40* 11	11 366 30-41* 16	9 629 30-45* 13	9 822 31-34* 13	8 024 27-39* 12
Mumbai	10 051 28-33 15	8 143 21-38 16	6 298 16-27 16	6 551 15-27 18	4 693 15-23 13
Santos	7 384 19-38 16	4 930 14-20 15	5 430 10-16 23	5 683 18-19 13	4 764 13-14 15

NB - *transit time including 2 transport legs and a transshipment.
Distances expressed in nautical miles.
Average speed for the shortest transit time.

Containerships: Influence of Service Speed

Service speed has a significant influence on the EEDI.

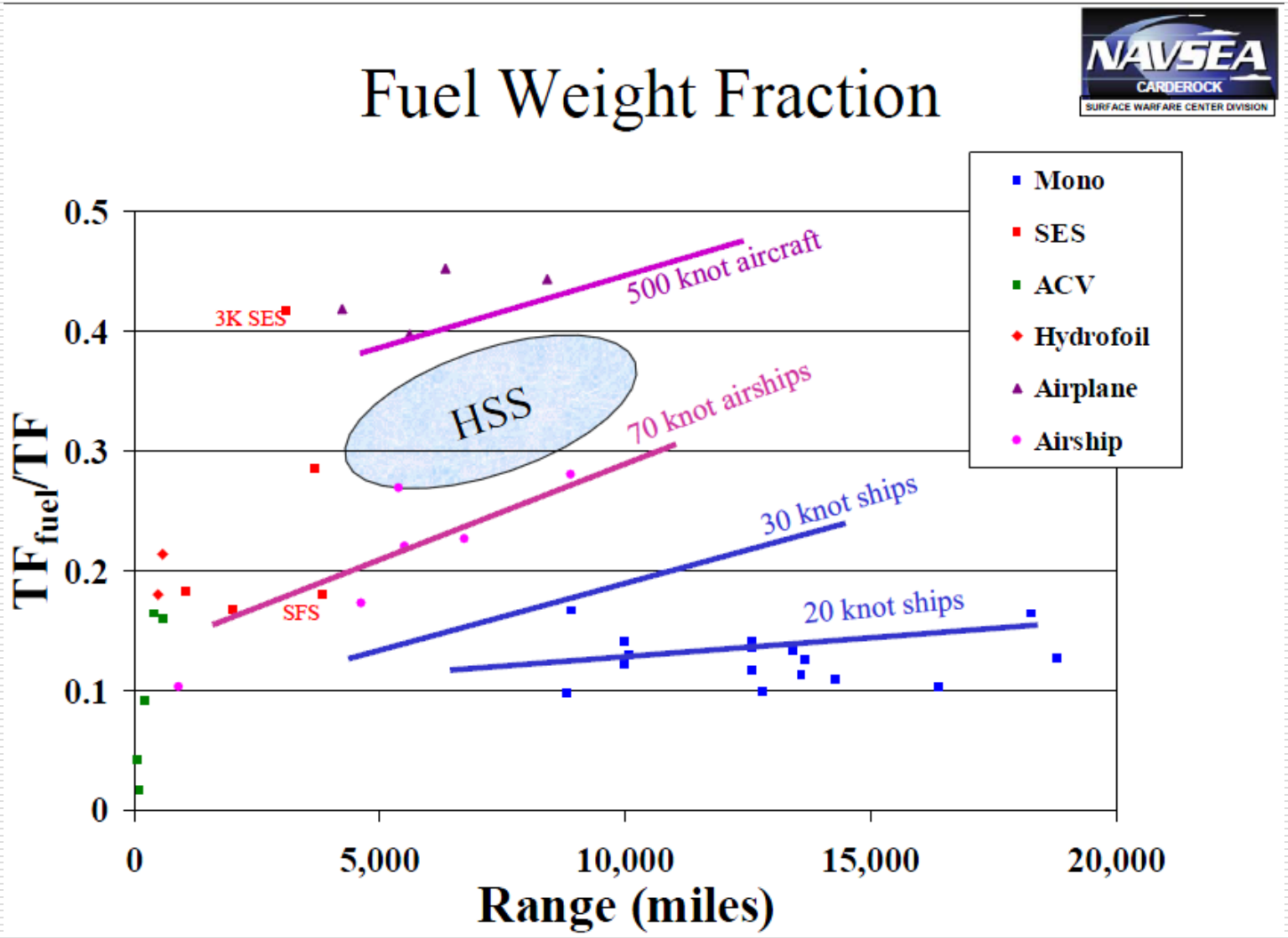
Design Speed Variation		-4 knots	-2 knots	Standard
1,000 TEU (Feedership)	$EEDI_A$	14.70	18.37	25.18
	% Change	-42%	-27%	---
4,500 TEU (Panamax)	$EEDI_A$	11.31	14.15	17.99
	% Change	-37%	-21%	---
4,500 TEU (Baby Neo-Panamax)	$EEDI_A$	11.34	14.39	18.64
	% Change	-39%	-23%	---
8,000 TEU (Post-Panamax)	$EEDI_A$	10.53	13.07	16.17
	% Change	-35%	-19%	---
12,500 TEU (Ultra Large)	$EEDI_A$	9.28	11.40	14.01
	% Change	-34%	-19%	---



HEC

ABS

Fuel weight fraction of various vehicles



A general concept of “cost”

Cost: any negative consequence we accept ourselves or cause others to experience in order to achieve a result.

- Monetary costs
- Time expended
- People placed at risk
- Injuries or deaths
- Environmental impacts
- Unpleasantness endured
- Societal disruption
- “Borrowed” systems