Current Methodologies and Best Practices for Preparing Ocean Going Vessel Emission Inventories Used in Preparing the U.S. ECA Proposal for U.S.EPA

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ECA Inventory Methodology

- **ECA Inventory used Corbett STEEM grid model**
- **STEEM not accurate around ports**
  - Assumes ships come in at full speed (no maneuvering)
  - Does not include hotelling emissions
- **EPA developed port inventories of 117 US Ports**
- **Grid cells around ports were replaced with new port inventories**
- **Air Quality Modeling performed on integrated grid**
  - Corbett STEEM + New Port Inventories

New Port Inventories

- **EPA used newest port emission inventory methodology**
- **Ocean going vessel movements were modeled at 117 US ports**
- **Transit zones (lower speed areas approaching ports due to navigational hazards) were determined for each port**
- **Time in modes were calculated for**
  - Cruise
  - Transit
  - Maneuvering
  - Hotelling

Sources for New Port Inventories

Current Methodologies and Best Practices – EPA

- Current Methodologies and Best Practices for Preparing Port Emission Inventories – April 2009

Starcrest Inventories

- 2005 Puget Sound Air Maritime Emissions Inventory -- 2007
- 2005 Port of Los Angeles Air Emissions Inventory -- 2007
- 2005 Port of Long Beach Air Emissions Inventory -- 2007
- 2006 Port of San Diego Air Emissions Inventory - 2007

Older EPA Guidance Documents

- Commercial Marine Activity for Deep Sea Ports in the United States -- 1999
- Commercial Marine Activity for Great Lakes and Inland River Ports in the United States – 1999
- Commercial Marine Emission Inventory Development -- 2002

Emissions Calculations

$$E = P \times LF \times A \times EF$$

Where E **= Emissions (grams [g])**

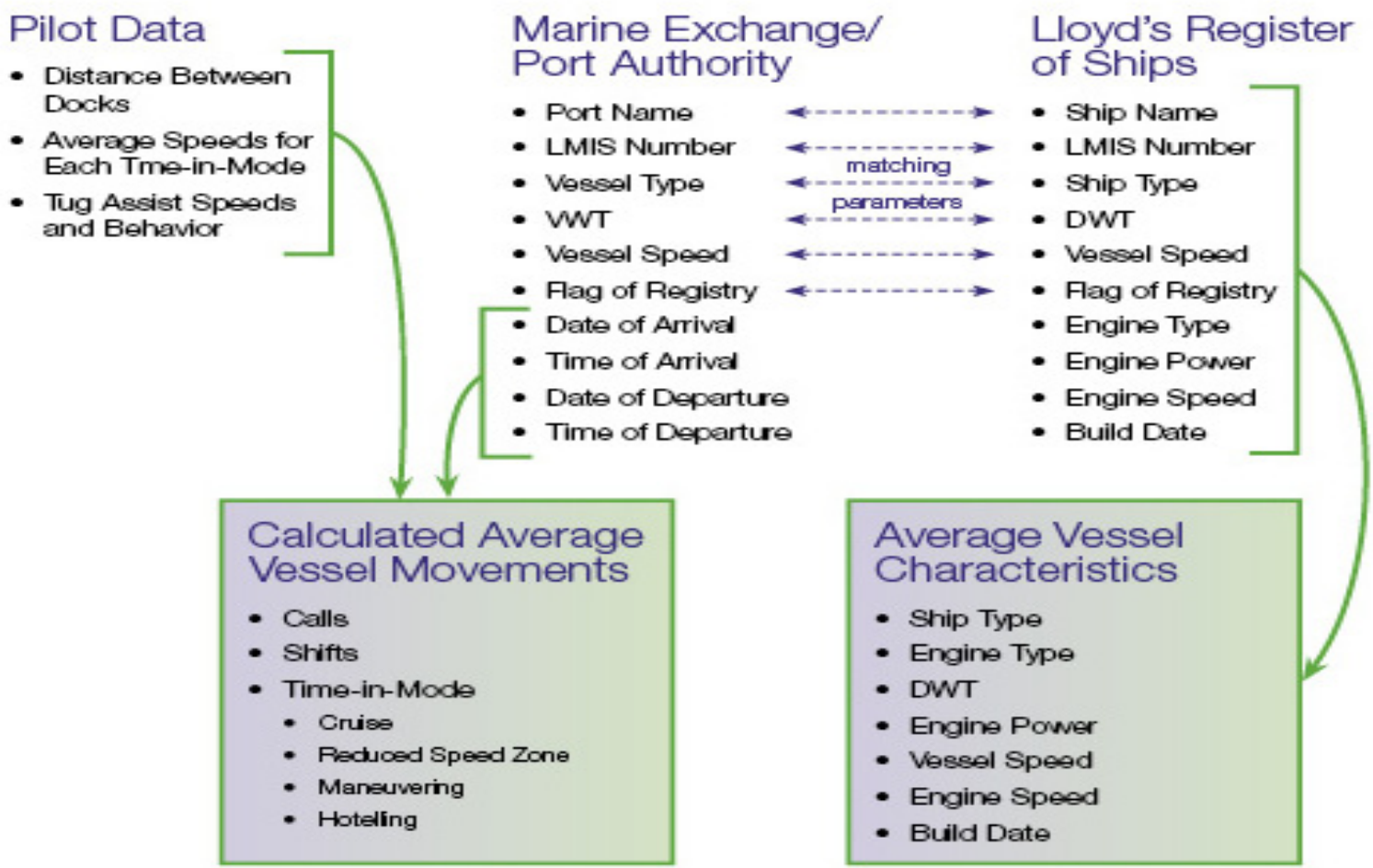
P **= Maximum Continuous Rating Power (kW)**

LF **= Load Factor (percent of vessel's total power)**

A **= Activity (hrs)**

EF **= Emission Factor (g/kWh)**

Data Sources



Ship Types

- Auto Carrier
- Barge Carrier
- Bulk Carrier
- Container
- General Cargo
- Miscellaneous
- Ocean Going Tug
- Passenger
- Reefer
- RoRo
- Tanker

Marine Engine Types

Engine Size

- Category 1
  - < 5 liters/cylinder
  - Mostly small harbor craft and recreational propulsion
- Category 2
  - > 5 liters/cylinder and < 30 liters per cylinder
  - OGV Auxiliaries, Harbor craft, smaller OGV propulsion
- Category 3
  - > 30 liters per cylinder
  - OGV propulsion

Marine Engine Types

- **Engine Speed**
  - Slow Speed
    - Direct Drive
    - Mostly 2 stroke
  - Medium Speed
    - Geared Drive
    - Mostly 4 stroke
    - > 300 rpm
  - High Speed
    - Geared Drive
    - 4 stroke
    - > 1400 rpm
- **Other Engine Types**
  - Steam Turbine
  - Gas Turbine
- **Electric Drive**
  - Auxiliary Engines used for both propulsion and auxiliary power

Auxiliary Engines

Ship Type	Average Propulsion Engine (kW)	Average Auxiliary Engines				Auxiliary to Prop Ratio
		Num	Power Each (kW)	Total Power (kW)	Engine Speed	
Auto Carrier	10,700	2.9	983	2,850	Medium	0.266
Bulk Carrier	8,000	2.9	612	1,776	Medium	0.222
Container	30,900	3.6	1,889	6,800	Medium	0.220
Cruise	39,600	4.7	2,340	11,000	Medium	0.278
General Cargo	9,300	2.9	612	1,776	Medium	0.191
RORO	11,000	2.9	983	2,850	Medium	0.259
Reefer	9,600	4.0	975	3,900	Medium	0.406
Tanker	9,400	2.7	735	1,985	Medium	0.211

Activity

- **Cruise**
  - From open ocean to Reduced Speed Zone (RSZ)
  - At service speed
- **Reduced Speed Zone**
  - From pilot pick-up or other point to breakwater
  - At reduced speed, usually 9 to 12 knots
- **Maneuvering**
  - From breakwater to berth
  - At slow speeds – 3 to 8 knots – slower coming in than out
- **Hotelling**
  - Time at berth or anchorage with propulsion engine off
  - Auxiliaries usually running unless cold ironing

Propulsion Engine Emission Factors (g/kWh)

Engine Type	Fuel Type	Sulfur	Emission Factors (g/kWh)							
			NOx	PM_{10}	$PM_{2.5}$	HC	CO	SOx	CO_2	BSFC
SSD	RO	2.70%	18.10	1.42	1.31	0.60	1.40	10.29	620.62	195
	MDO	1.00%	17.00	0.45	0.42	0.60	1.40	3.62	588.79	185
	MGO	0.50%	17.00	0.31	0.28	0.60	1.40	1.81	588.79	185
	MGO	0.10%	17.00	0.19	0.17	0.60	1.40	0.36	588.79	185
MSD	RO	2.70%	14.00	1.43	1.32	0.50	1.10	11.24	677.91	213
	MDO	1.00%	13.20	0.47	0.43	0.50	1.10	3.97	646.08	203
	MGO	0.50%	13.20	0.31	0.29	0.50	1.10	1.98	646.08	203
	MGO	0.10%	13.20	0.19	0.17	0.50	1.10	0.40	646.08	203
GT	RO	2.70%	6.10	1.47	1.35	0.10	0.20	16.10	970.71	305
	MDO	1.00%	5.70	0.58	0.53	0.10	0.20	5.67	922.97	290
	MGO	0.50%	5.70	0.35	0.32	0.10	0.20	2.83	922.97	290
	MGO	0.10%	5.70	0.17	0.15	0.10	0.20	0.57	922.97	290
ST	RO	2.70%	2.10	1.47	1.35	0.10	0.20	16.10	970.71	305
	MDO	1.00%	2.00	0.58	0.53	0.10	0.20	5.67	922.97	290
	MGO	0.50%	2.00	0.35	0.32	0.10	0.20	2.83	922.97	290
	MGO	0.10%	2.00	0.17	0.15	0.10	0.20	0.57	922.97	290

Propulsion Load Factors

$$LF = (AS/MS)^3$$

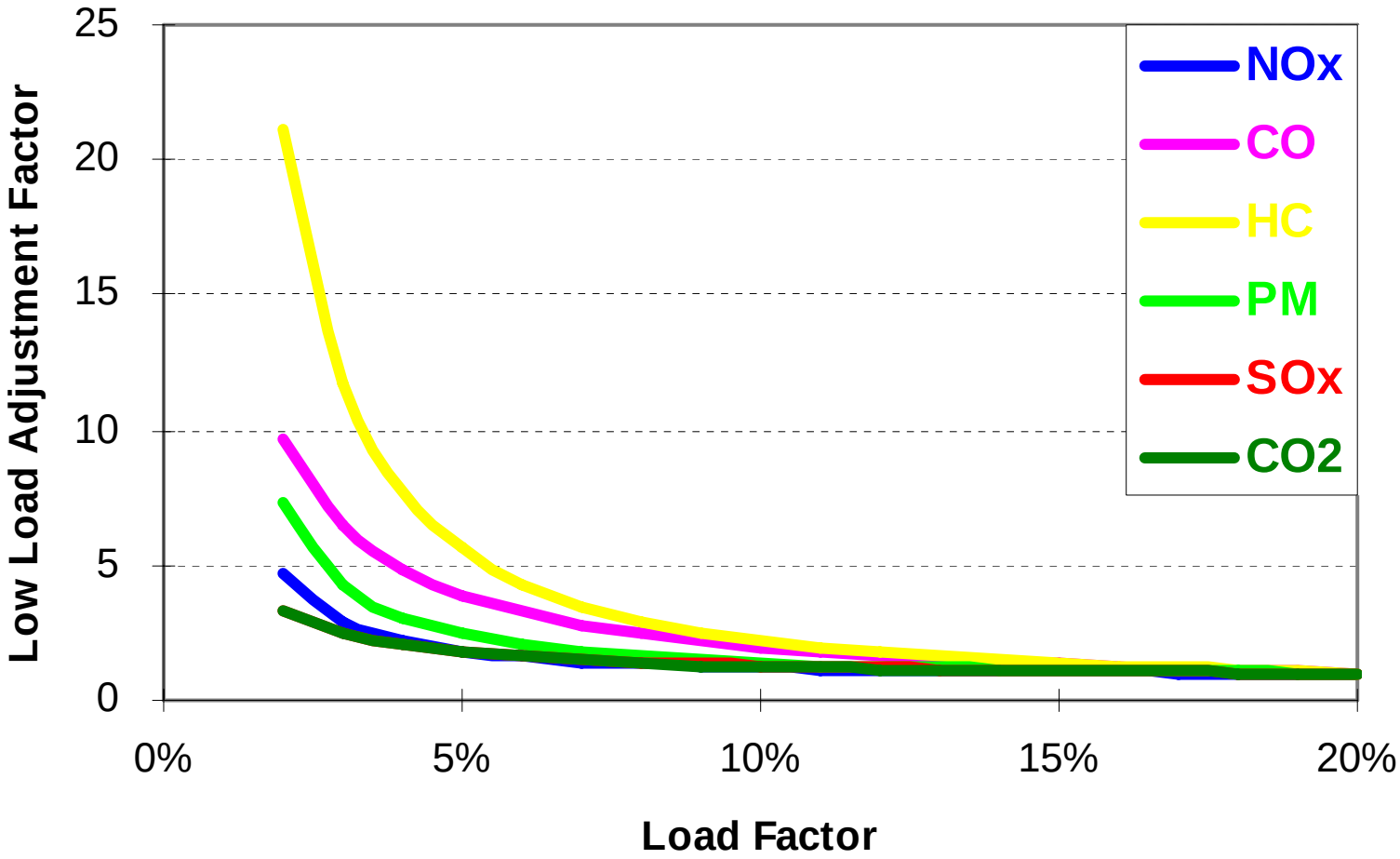
Where LF = Load Factor (percent)

AS = Actual Speed (knots)

MS = Maximum Speed (knots))

Minimum value 2%

Low Load Adjustment Factor



Auxiliary Engine Load Factors

Ship-Type	Cruise	RSZ	Maneuver	Hotel
Auto Carrier	0.13	0.30	0.67	0.24
Bulk Carrier	0.17	0.27	0.45	0.22
Container Ship	0.13	0.25	0.50	0.17
Cruise Ship	0.80	0.80	0.80	0.64
General Cargo	0.17	0.27	0.45	0.22
Miscellaneous	0.17	0.27	0.45	0.22
OG Tug	0.17	0.27	0.45	0.22
RORO	0.15	0.30	0.45	0.30
Reefer	0.20	0.34	0.67	0.34
Tanker	0.13	0.27	0.45	0.67

Auxiliary Engine Emission Factors (g/kWh)

Fuel Type	Emission Factors (g/kWh)								
	Sulfur	NOx	PM_{10}	$PM_{2.5}$	HC	CO	SOx	CO_2	BSFC
RO	2.70%	14.7	1.44	1.32	0.40	1.10	11.98	722.54	227
MDO	1.00%	13.9	0.49	0.45	0.40	1.10	4.24	690.71	217
MGO	0.50%	13.9	0.32	0.29	0.40	1.10	2.12	690.71	217
MGO	0.10%	13.9	0.18	0.17	0.40	1.10	0.42	690.71	217

New IMO Regulations

Area	Year	Fuel Sulfur	NOx
Emission Control Area	Today to Jul 2010	15,000 ppm	
	2010	10,000 ppm	
	2015	1,000 ppm	
	2016		Tier 3 Aftertreatment*
Global	Today to Jan 2012	45,000 ppm	
	2012	35,000 ppm	
	2020	5,000 ppm	
	2011		Tier 2 Engine Controls*

* Today's Tier 1 NOx standards range from approximately 10 to 17 g/kW-h, depending on engine speed. The Tier 2 standards represent a 20% NOx reduction below Tier 1, and the Tier 3 standards represent an 80% NOx reduction below Tier 1.

NOx Emission Reductions for IMO Regulations

Analysis Year	Global		Emission Control Area	
	Main	Auxiliary	Main	Auxiliary
2005	9.8%	9.4%	9.8%	9.4%
2010	12.5%	12.3%	12.5%	12.3%
2015	19.8%	19.4%	19.8%	19.4%
2020	24.3%	25.2%	40.4%	41.6%
2025	26.8%	28.3%	57.2%	58.9%
2030	28.5%	30.5%	68.2%	70.1%

Emission Reduction Calculations

- Emission Inventories from ships calculated using EPA Best Practices Document
- Available at

http://www.epa.gov/sectors/sectorinfo/sectorprofiles/ports.html

- Contact Info

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