Current Methodologies and Best Practices for Preparing Port Emission Inventories

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Why Do a Port Emissions Inventory?

▶ Development of a well-informed port emissions reduction strategy

▶ SIP development

▶ NEPA and CEQA analyses

Port Inventory Development Methodology Options

▼ **Detailed Inventory**
  – Requires details on deep sea vessel and land based equipment characteristics, activities, port geometry and ship paths
  – Used by larger sea ports
  – Resource Intensive

▼ **Mid-Tier Inventory**
  – Requires port-specific activity information by ship type then applies "typical" port emission rate averages for each ship type
  – Used by mid-sized and smaller ports in a non-attainment or maintenance areas

� Streamlined Inventory

– Requires minimal port-specific details
– Extrapolates emission data from another port using US ACE ship trip data and RSZ speed and distance
– Provides a "back of the envelope" estimate of port emissions
– Used by smaller sea and Great Lake ports
– Low amount of resources required

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

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)

Pilot Data

- Distance Between Docks
- Average Speeds for Each Tme-in-Mode
- Tug Assist Speeds and Behavior

Marine Exchange/ Port Authority

- Port Name
- LMIS Number
- Vessel Type
- VWT
- Vessel Speed
- Flag of Registry
- Date of Arrival
- Time of Arrival
- Date of Departure
- Time of Departure

matching parameters

Lloyd's Register of Ships

- Ship Name
- LMIS Number
- Ship Type
- DWT
- Vessel Speed
- Flag of Registry
- Engine Type
- Engine Power
- Engine Speed
- Build Date

Calculated Average Vessel Movements

- Calls
- Shifts
- Time-in-Mode
  - Cruise
  - Reduced Speed Zone
  - Maneuvering
  - Hoteling

Average Vessel Characteristics

- Ship Type
- Engine Type
- DWT
- Engine Power
- Vessel Speed
- Engine Speed
- Build Date

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
- < 130 rpm
- Mostly 2 stroke

– Medium Speed
- > 130 rpm and < 1400 rpm
- Mostly 4 stroke

– High Speed
- > 1400 rpm
- 4 stroke

▸**Other Engine Types**

– Steam Turbine
– Gas Turbine

Auxiliary Engines

Ship Type	Average Propulsion Engine (kW)	Average Auxiliary Engines				Auxiliary to Prop Ratio
		No	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

▼ **Cruise**
- From open ocean to 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 Load Factors

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

Where LF = Load Factor (percent)

AS = Actual Speed (knots)

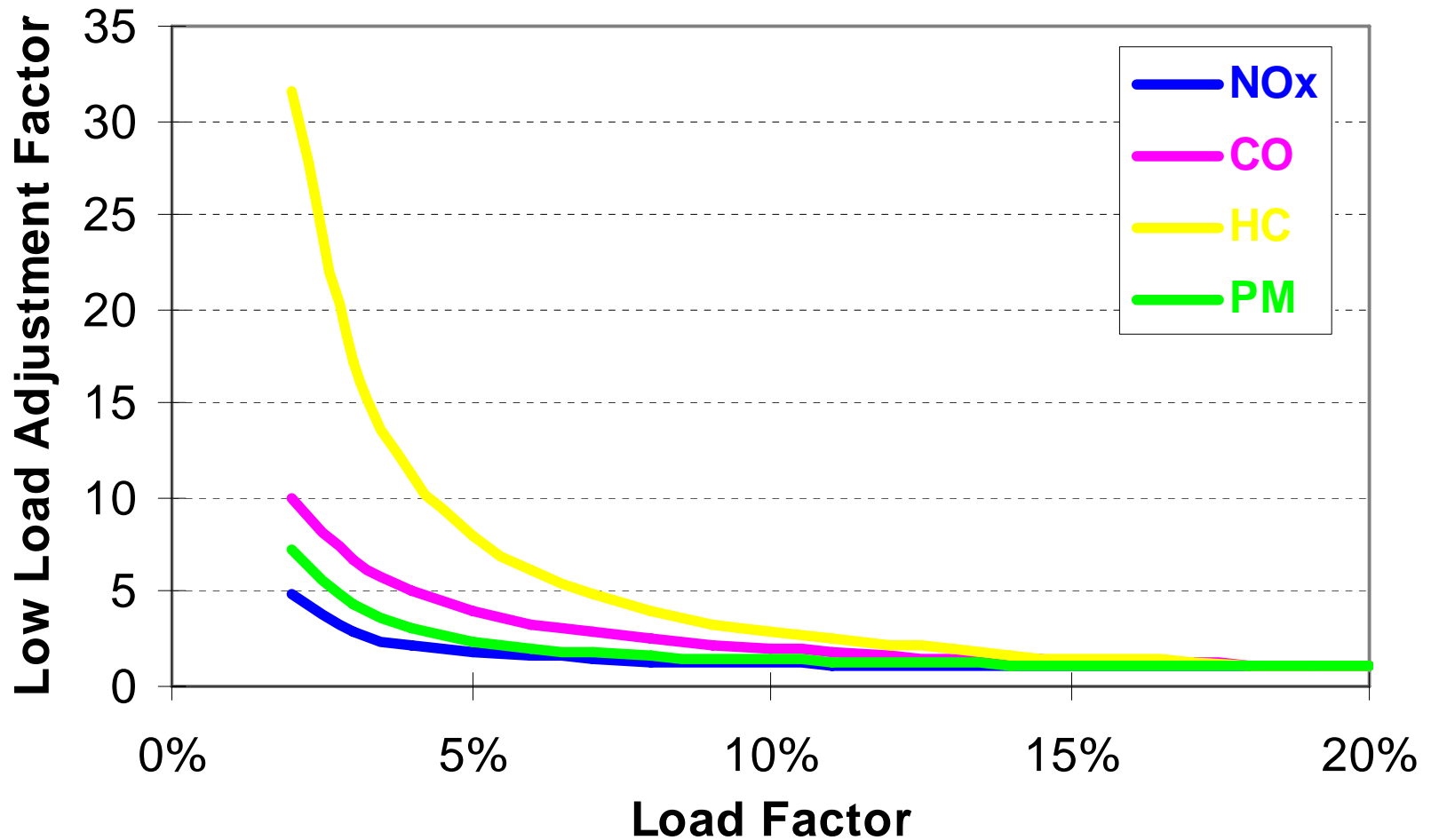MS = Maximum Speed (knots))

Minimum value 2%

Propulsion Engine Emission Factors (g/kWh)

Engine	NOx	CO	HC	PM_{10}	$PM_{2.5}$	SO_2
SSD	18.1	1.40	0.60	1.05	0.96	10.3
MSD	14.0	1.10	0.50	1.11	1.02	11.1
ST	2.1	0.20	0.10	1.50	1.38	16.1

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	% S	NOx	CO	HC	PM_{10}	$PM_{2.5}$	SO_2
RO	**2.7**	14.70	1.10	0.40	1.11	1.02	11.1
MDO	**1.5**	13.90	1.10	0.40	0.71	0.66	6.16
MGO	**0.5**	13.90	1.10	0.40	0.38	0.35	2.05

Harbor Craft

- Assist tugboats
- Towboats/pushboats/tugboats
- Ferries and excursion vessels
- Crew boats
- Work boats
- Government vessels
- Dredges and dredging support vessels
- Commercial fishing vessels
- Recreational vessels

Land Side Emission Sources
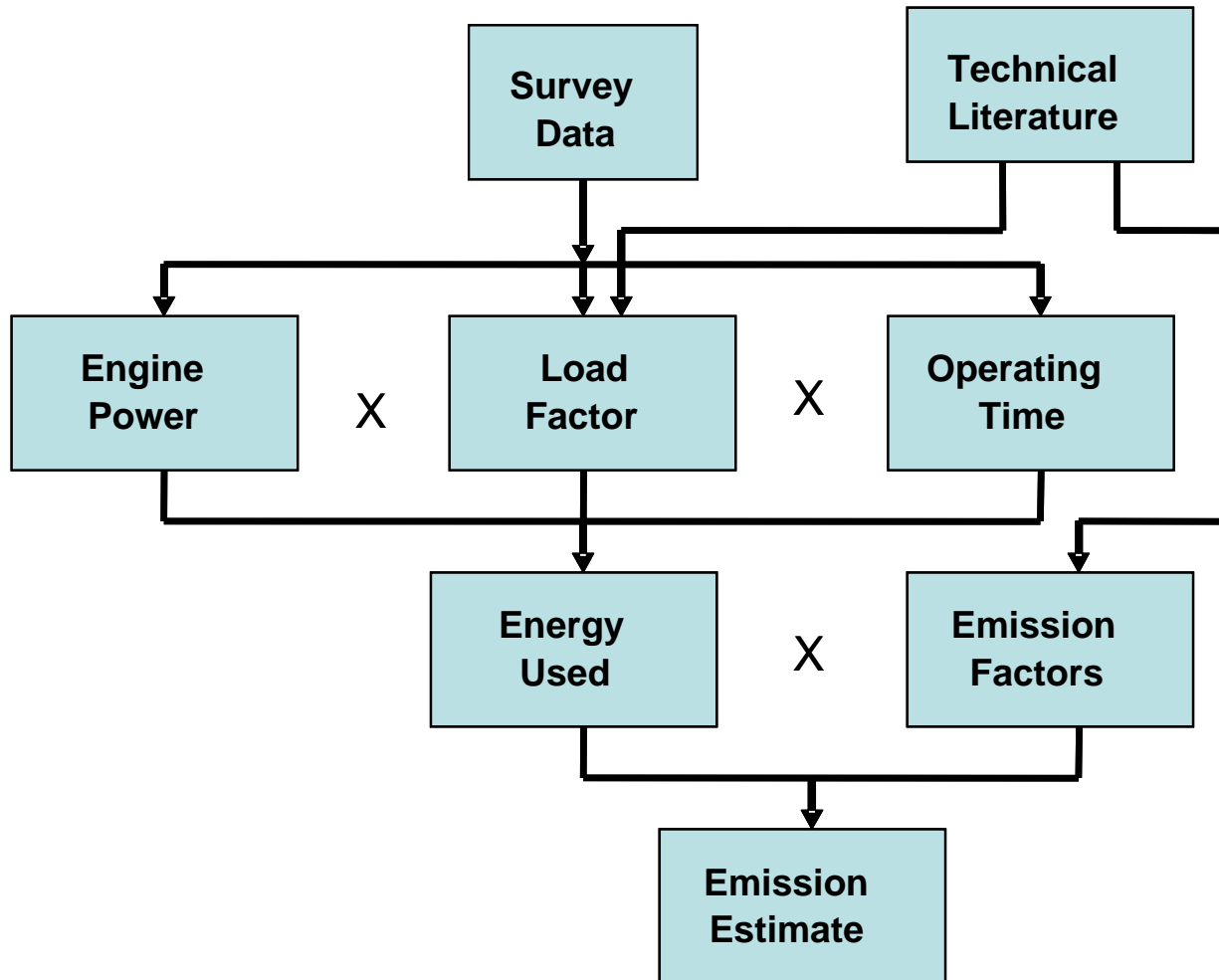
- Cargo Handling Equipment
  - Determine counts by equipment type
  - Determine activity
  - Use Nonroad Model to calculate emissions
- Rail
  - Information from Rail companies
  - Apply EPA guidance
- On-road vehicles
  - Determine fleet calling on port
  - Use MOBILE 6.2 to calculate emissions
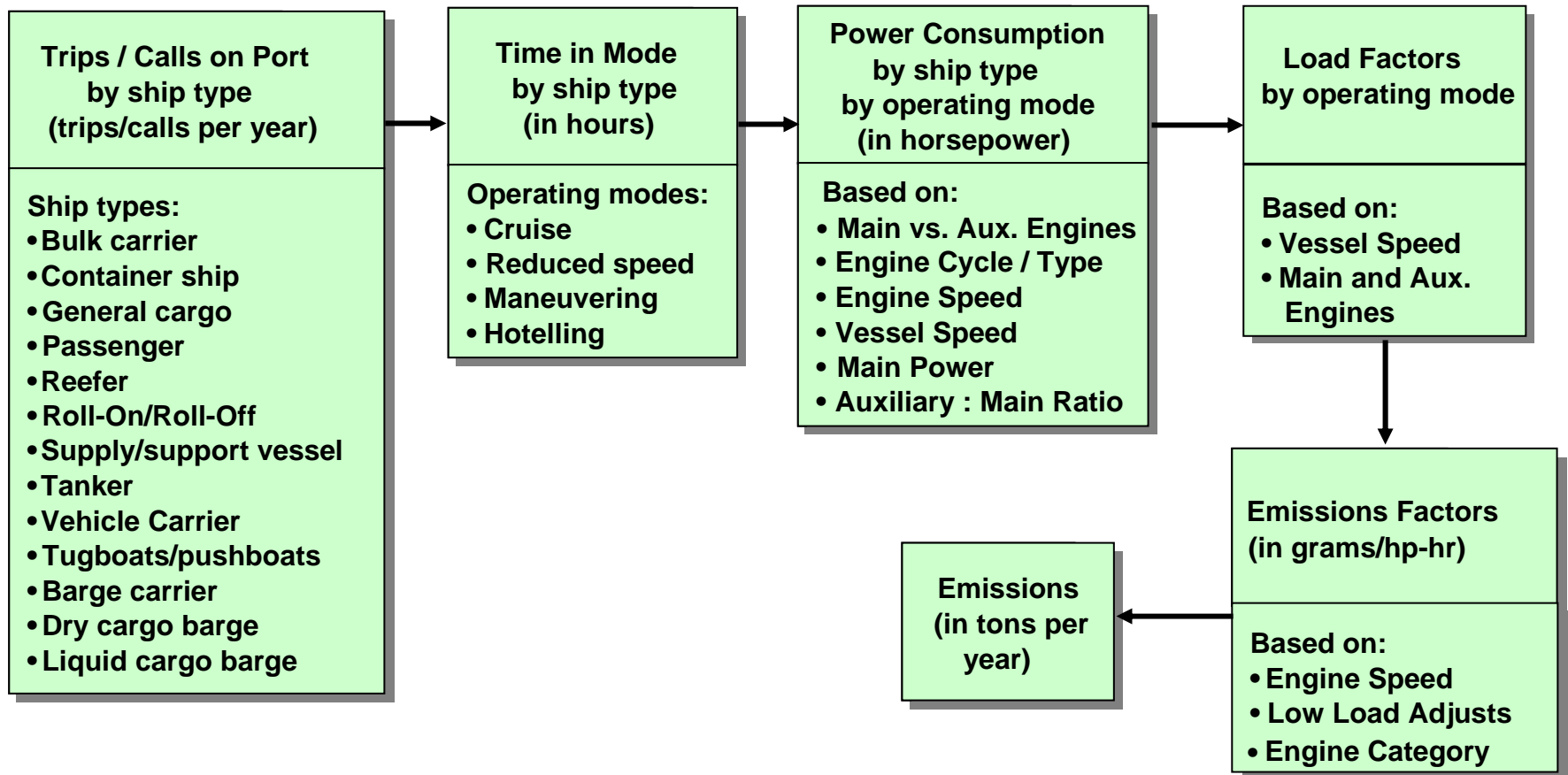
Great Lake and Inland River Ports
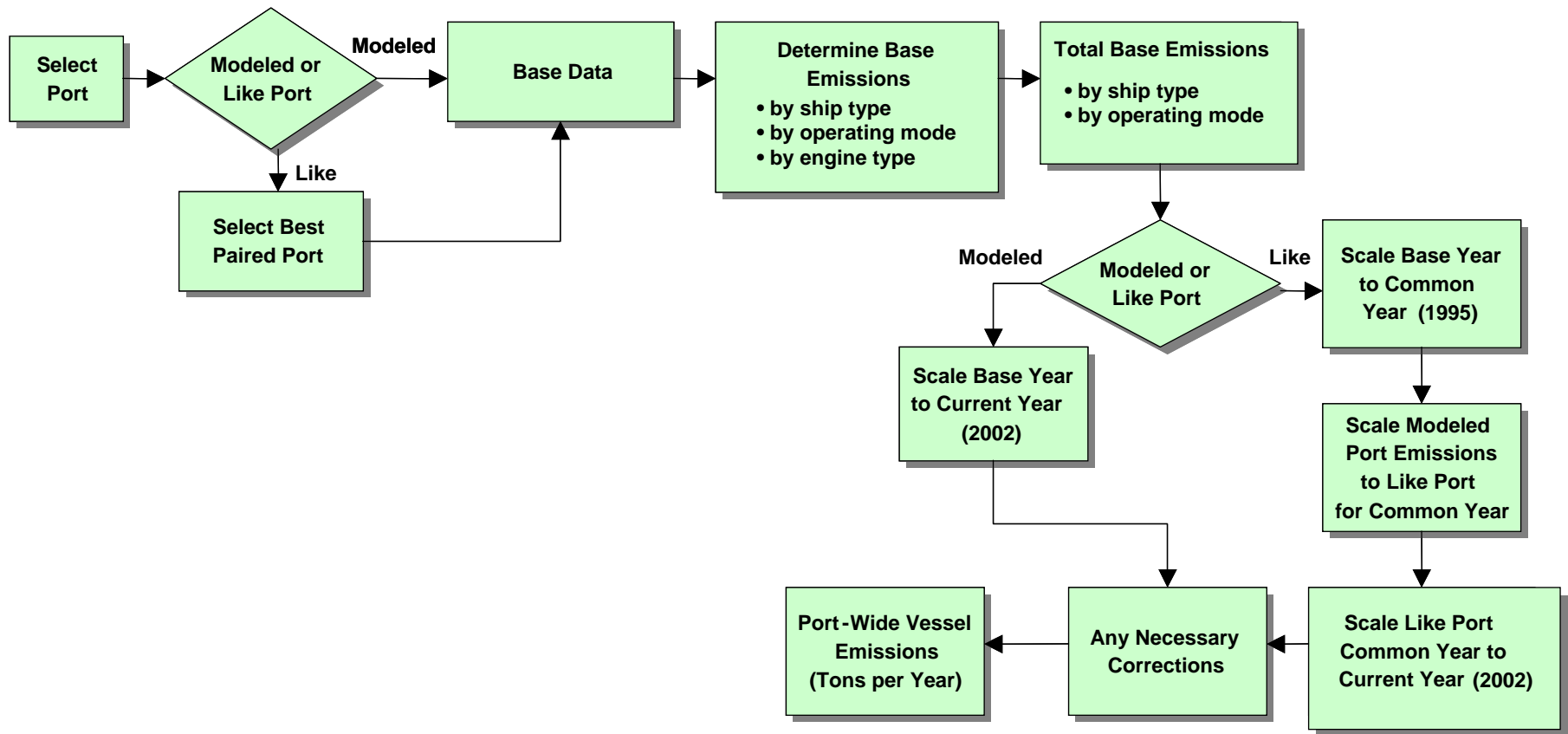
Great Lake Ports

– Ship Types differ from Deep Sea Ports
  - Salties – Pass through the St. Lawrence River to the Ocean
  - Lakers – Stay within the lakes

– Significant amount of trips by tug/barge and Category 2 ships

Inland River Ports

– Entirely tug/barge and excursion vessels

– Entirely Category 2 ships

– Significant amount of traffic passes ports without stopping

Mid-Tier Method

Trips / Calls on Port by ship type (trips/calls per year)

Ship types:
- Bulk carrier
- Container ship
- General cargo
- Passenger
- Reefer
- Roll-On/Roll-Off
- Supply/support vessel
- Tanker
- Vehicle Carrier
- Tugboats/pushboats
- Barge carrier
- Dry cargo barge
- Liquid cargo barge

→

Time in Mode by ship type (in hours)

Operating modes:
- Cruise
- Reduced speed
- Maneuvering
- Hotelling

→

Power Consumption by ship type by operating mode (in horsepower)

Based on:
- Main vs. Aux. Engines
- Engine Cycle / Type
- Engine Speed
- Vessel Speed
- Main Power
- Auxiliary : Main Ratio

→

Load Factors by operating mode

Based on:
- Vessel Speed
- Main and Aux. Engines

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Emissions Factors (in grams/hp-hr)

Based on:
- Engine Speed
- Low Load Adjusts
- Engine Category

←

Emissions (in tons per year)

Streamlined Method

More Information

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▸ EPA Marine Inventory Guidance
  – http://www.epa.gov/otaq/marine.htm
▸ EPA Port Sectors Website
  – http://www.epa.gov/sectors/ports