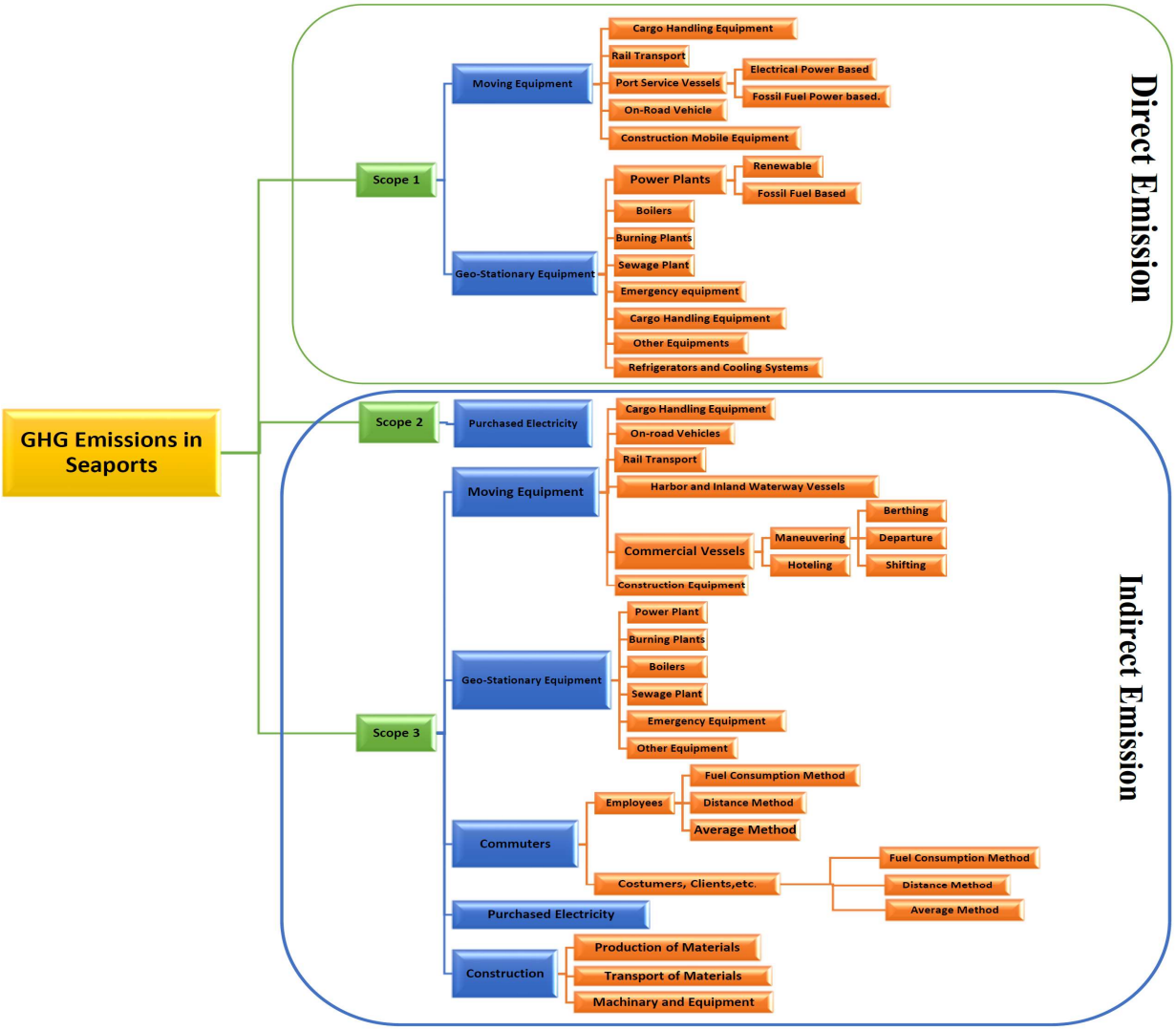

Figure 2. Overview of Emission Categories and Scopes in Ports.

1. Emission Scopes

$$\text{Emission} = \sum_{i=1}^{3} E_{\text{scope i}} \quad (1)$$

1.1. Scope 1

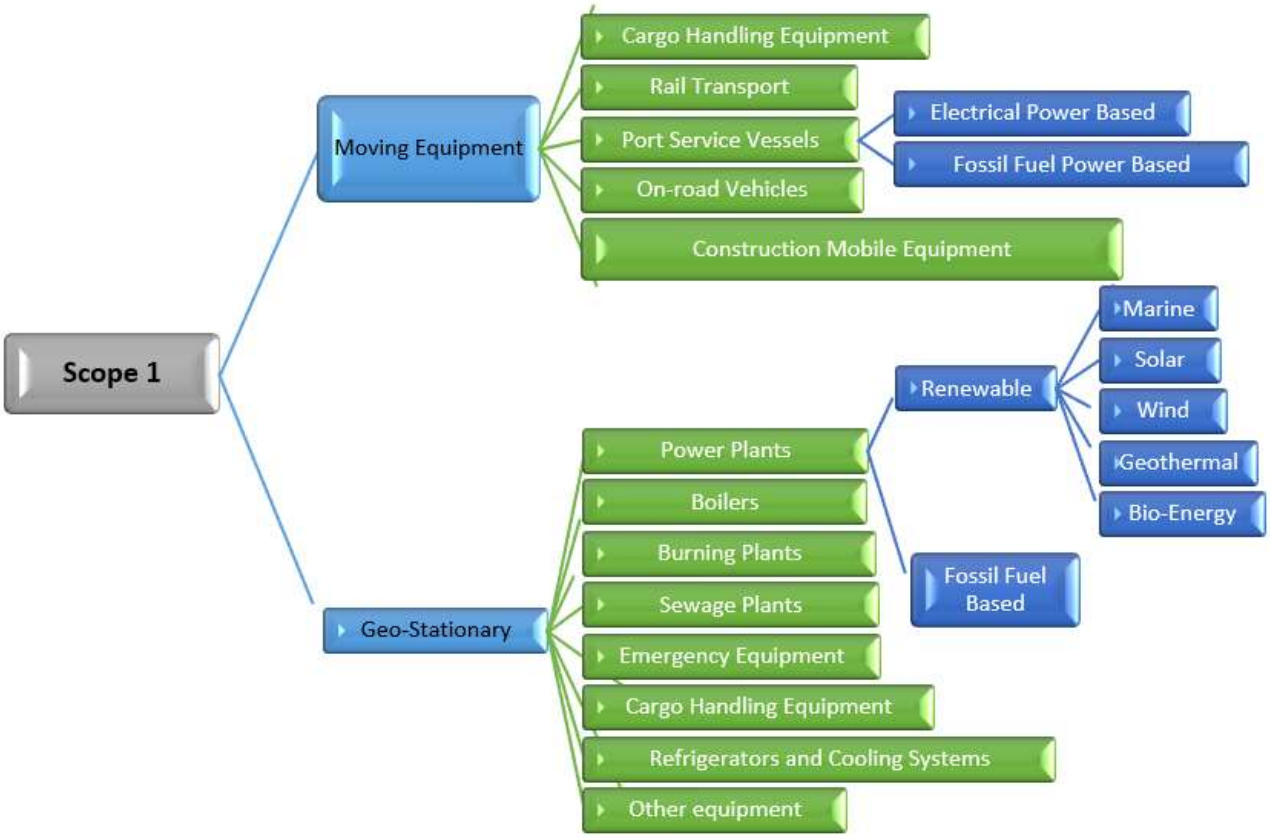

Figure 3. Overview of Subsections of Scope 1 in a Seaport.

The emissions' equation in Scope 1 can be formulated as follows:

$$\text{Emission}_{\text{scope 1}} = \sum_{i=1}^{n} \text{Emission}_{n} \quad (2)$$

where $\text{Emission}_{\text{scope 1}}$ is the total mass of Co_{2eq} emissions of the scope (tones), Emission_{n} is each source's total emissions (tones).

- *Moving Equipment Category*
  1. *Cargo Handling Equipment*

(a) $$\text{Emission}_{i} = \sum_{i=1}^{n} \text{Fuel Consumption}_{i} \times EF \quad \text{(Standard Formula)} \quad (3)$$

or

(b) $$\text{Emission}_{i} = \sum_{i=1}^{n} T \times A.C_{i} \times EF \quad \text{(Formula A)} \quad (4)$$

Or

$$\text{Emission}_{i} = \sum_{i=1}^{n} D.C_{1}.EF + \sum_{i=1}^{n} T.C_{2}.EF$$

"EF" is the emission factor of consumed fuel (kg Co_{2eq}/litter).
"T" is the time of equipment operation in an hour.

"$A.C_i$" is the average consumption of equipment as per the instruction manual and manufacture specification sheet.
"EF" is the emission factor of consumed fuel (kg Co_{2eq}/litter).
"D" is the total distance travelled (km) inside the port boundary,
"C_1" is the average fuel consumption (L/km),
"T" is the average running time of equipment or machinery.
"C_2" is the average fuel consumption per hour (L/h).
"EF" is emission factor of consumed fuel (kg Co_{2eq}/litter).

2. *Rail Transport Equipment*

$$\text{Emission}_i = M \times D \times C \times EF \quad (5)$$

"M" is the total volume of cargo handled inside the port border by rail transport (tone).
"D" is the total distance of rail transport inside the port (kilometre).
"C" is the average locomotive fuel consumption (tones/kilometre).
"EF" is fuel emission factor (kg Co_{2eq}/lit).

3. *Port Service Vessels*

two main categories: electrical power-based and fossil fuel-based.
The "Standard Formula" can apply.

4. *On Road Vehicles*

- the "Standard Formula",
- "Formula A "for these vehicles.

5. *Mobile Construction Equipment*

$$\text{Emission}_i = \sum_{i=1}^{n} D \,.\, C_1 \,.\, EF + \sum_{i=1}^{n} T \,.\, C_2 \,.\, EF \quad (6)$$

"D" is the total distance travelled (km) inside the port boundary.
"C_1" is the average fuel consumption per kilometre (L/km).
"T" is the average running time of equipment or machinery.
"C_2" is the average fuel consumption per hour (L/h).
"EF" is emission factor of consumed fuel (kg Co_{2eq}/litter).

- *Geo-Stationary Equipment Category*

1. *Power Plants, Boilers, Burning Plants, Sewage Plants and Emergency and Cargo Handling Equipment*

- "Standard Formula".
- "Formula A".

2. *CF of Refrigerators and Cooling Systems*

GWP and is equal to emissions due to the following formula:

$$E_n^i\,(CO_2\,eq) = E_n^i . GWP^i \quad (7)$$

GWP^i = global warming potential of each gas (tones Co_{2eq}/tones gas).

- *Other Equipment*

all other fixed equipment

- "Standard Formula"
- "Formula A" method, or
- the "hybrid method" as follows:

$$\text{Emission}_i = \sum_{i=1}^{n} D \,.\, A \,.\, C_1 \,.\, EF + \sum_{i=1}^{n} T \,.\, A \,.\, C_2 \,.\, EF \quad (8)$$

"EF" is the emission factor of consumed fuel (kg Co_{2eq}/litter).
"T" is the time of equipment operation in an hour.
"$A.C_i$" is the average consumption of equipment as per the instruction manual and manufacture specification sheet.
"EF" is the emission factor of consumed fuel (kg Co_{2eq}/litter).
"D" is the total distance travelled (km) inside the port boundary,
"C_1" is the average fuel consumption (L/km),
"T" is the average running time of equipment or machinery.
"C_2" is the average fuel consumption per hour (L/h).
"EF" is emission factor of consumed fuel (kg Co_{2eq}/litter).

2. Scope 2

$$\text{Emission}_{\text{scope 2}} = \sum_{i=1}^{n} \text{Purchased Electricity}_i \times EF \quad (9)$$

"Purchased Electricity$_i$" is total amount of Electricity Consumption in the port authority(kwh).
"EF" is the CO_2 Emission Factor (kg Co_{2eq}/KWh).

3. Scope 3

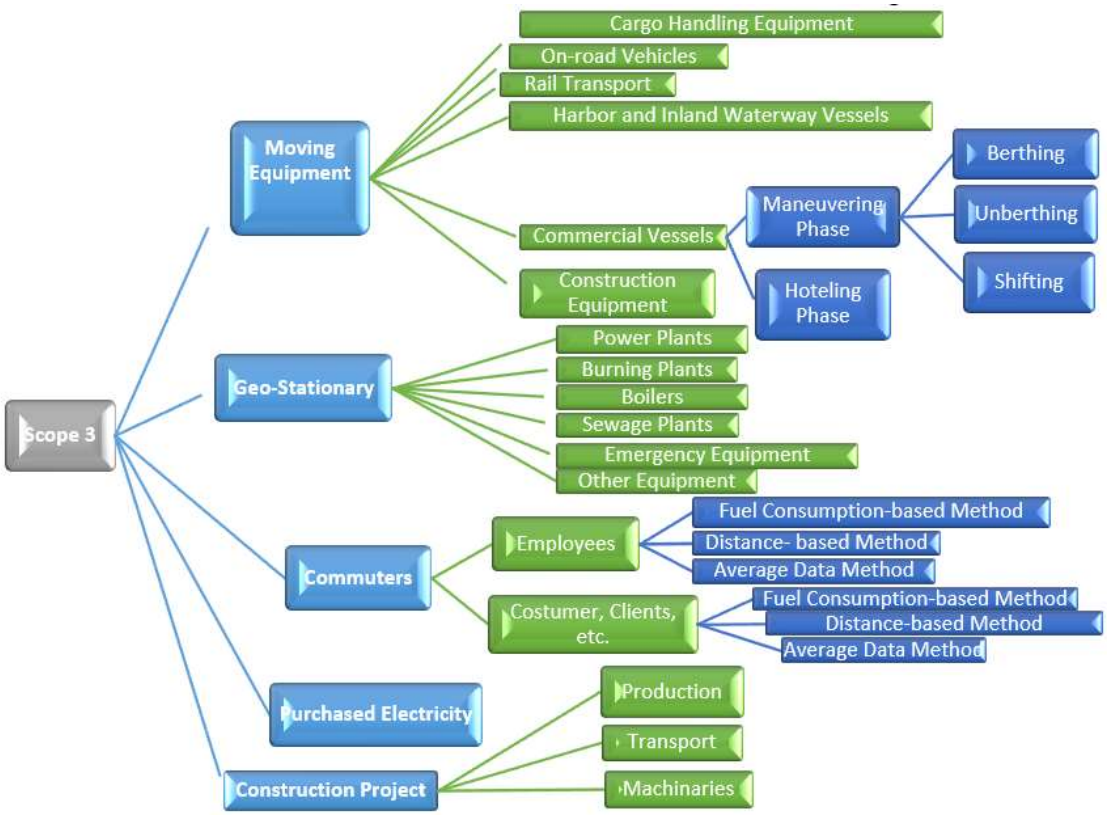

Figure 7. Overview of Subsections of Scope 3 in a Seaport.

- *Moving Equipment*

i. *Cargo Handling Equipment*

$$\text{Emission}_i = P_i \times L.F_i \times T_i \times C_i \quad (10)$$

"P_i "is the total power of the engines of the mobile equipment in kW.
"$L.F_i$ " is the load factor of each machinery that can be retrieved from approved inventories and published by CARB (The California Air Resources Board),
"T_i" is the total running time in an hour.
"C_i" is the fuel consumption per unit of power consumed (g/kWh).

ii. On Road Vehicles

Trucks, lorries, and other on-road vehicles used to transport cargo inside ports:

$$\text{Emisssion}_i = \sum_{i=1}^{n} D_i \times \text{Ave.}\, C_D \times EF + \sum_{i=1}^{n} T_i \times \text{Ave}.\, C_T \times EF \quad (11)$$

"I" is the number of trucks.
"D" is the total distance travelled in KM inside the port boundary as defined for this study.
"Ave. C_D" is the average fuel consumption in litres/kilometre.
"T" is the average running time of a truck in hours.
"Ave. C_T " is the average fuel consumption in litres/hour.
"EF" is the emission factor of the consumed fuel.

iii. Rail Transport Equipment

Rail transport inside port boundaries:

$$\text{Emission}_i = M \times D \times C \times EF \quad (12)$$

"M" is the total amount of cargo handled inside the port boundary by rail transport(tone).
"D" is the total distance of rail transport inside the port (by kilometre).
"C" is the average fuel consumption of locomotive (tones/kilometre).
"EF" is emission factor (kg Co_{2eq}/litre).

iv. Harbour and Inland Waterway Vessels

- "Standard Formula" calculates total emission, whereas their emission can be estimated as follows too:

$$\text{Emission}_i = P_i \times L.F_i \times T_i \times C_i \quad (13)$$

"P_i " is the total power of the motors of the vessel in kW.
"$L.F_i$ " is the load factor published by national and international communities such as CARB (The California Air Resources Board).
T_i" Is =021the total running time in an hour.
"C_i" is the fuel consumption per unit of power consumed (g/kWh).

v. Commercial Vessels

In (A) berthing, (B) unberthing (departure), and (C) in port shifting:

$$\text{Emission}_i = \sum_{i=1}^{n} (M.E.P \times LF \times T)_i \times EF \quad (14)$$

"M.E.P" is the maximum engine power of the vessel in kw.
"T" is the time of ships maneuvering in hours.
"LF" is the load factor of the vessels that the following formula can obtain:

$$LF = (\text{manuevering speed} / \text{max speed})^3 \quad (15)$$

The maximum speed can be obtained in the vessel's specification sheet.

vi. Construction Equipment

$$\text{Emission}_i = P_i \times L.F_i \times T_i \times C_i \quad (16)$$

"P_i " is the total power of the motors of the mobile equipment in kW.
"$L.F_i$ " is the load factor published by CARB (The California Air Resources Board).

" T_i" is the total running time in an hour.
"C_i" is the fuel consumption per unit of power consumed (g/kWh).

- *Geo-Stationary*

  - The "Standard Formula".
  - "Formula A".

- *Commuters*

The "Standard Formula", distance travel method, and hybrid or average data methods calculates interior port commuter emissions as follows:

$$\text{Emission}_i = \sum_{i=1}^{n} D_i \times A.C_i \times EF \quad (20)$$

or

$$\text{Emission}_i = \sum_{i=1}^{n} A.D \times W.D \times P.N \times EF \quad (21)$$

"D" is the travelled distance of cars by kilometers.
"$A.C_i$" is the average consumption of the car (Litter/Kilometre).
"A.D" is the average travelled distance of commuters.
"W.D" is the working days of the period under study.
"P.N" is the personnel number that commuting to the ports.
"EF" is the emission factor of consumed fuel of cars in (kg Co_{2eq}/litter).

- *Purchased Electricity*

$$\text{Emission}_i = \sum_{i=1}^{n} \text{Purchased Electricity}_i \times EF \quad (22)$$

"$\text{Purchased Electricity}_i$" is total amount of Electricity Consumption in the port authority(kwh).
"EF" is the CO_2 Emission Factor (kg Co_{2eq}/KWh).

- *Calculation of Other Indirect GHG Emission Including Construction, Production and Transport of Materials*

1. *Production of Construction Used Materials*

The amount of each material anticipated to be used will be divided by the "cradle-to-gate" emissions factor for each material unit to calculate the emissions for the component's work.

Port projects typically employ borrowed material for filling, aggregate types in larger amounts, concrete and steel for reinforcing, and materials for paving dykes, esplanades, and roadways.

The project's measurements and standard sections will figure out how much of each material will be used in each phase, and national organizations usually publish the inventory of emissions of significant materials used in seaport projects. It must be applied in scope three emissions.

2. *Transport of Construction Materials.*

- "Standard Formula".

$$\text{Emission}_i = \sum_{i=1}^{n} D_i \times A.C_i \times EF \quad (23)$$

or

$$\text{Emission}_i = \sum_{i=1}^{n} \text{A.D} \times \text{W.D} \times \text{V.N} \times \text{EF} \quad (24)$$

"D" is the travelled distance of trucks by kilometres.
"A.C_i" is the average consumption of the trucks (litres/kilometre).
"A.D" is the average travelled distance of the vehicle from the gate of the port to discharging.
"W.D" is the working days of the period under study.
"V.N" is the number of trucks that commute to the ports.
"EF" is the emission factor of consumed fuel of trucks in (kg Co_{2eq}/litter).

- *Emissions of Machinery and Other Equipment Used in Construction*

- "Standard Formula".