CHAPTER 3

ENERGY ACCOUNTING AND GHG INVENTORIES

3.1 ENERGY CONSUMPTION FROM VARIOUS SOURCES AT PORT OF CHENNAI

Electricity, Diesel, Petrol and LPG are the major sources of energy at port of Chennai. Diesel and electricity are majorly consumed for port related activities such as diesel generators, diesel operated cranes, tug boats, mooring launches, vehicle transport and electrical motors for operation of cranes, pumps and reefer (refrigerated vessels) containers. Petrol is used generally for vehicle transportation. LPG cylinders are used in housing colony for cooking applications.

A detailed energy consumption pattern due to port owned activities and the activities by port tenants and users are arrived by conducting an energy auditing. The instruments used for the energy and emissions measurements are i) Power analyzer (Fluke), ii) clamp on energy meter, iii) flue gas analyzer, iv) thermo anemometer and v) lux meter.

3.1.1 Diesel Consumption Pattern

The port of Chennai, the fourth largest Indian port in terms of throughput, is one of the major ports of India situated on the Coramandel coast with a handling capacity of 86.04 million tonnes (Mt) per annum. It uses
enormous amount of electricity and diesel for intermodal transportation of goods and for providing various other essential services. The port is powered by the electricity received from the Tamil Nadu Generation and Distribution Corporation (TANGEDCO) and uses diesel for trucks, diesel generators, rail locomotives and diesel operated cranes.

The port has 24 berths for cargo handling, distributed along three docks and has an entrance channel of 7 km. The major diesel consumers are tug boats, diesel locomotives, mooring launches and transfer cranes. The diesel operated cranes are located in the container terminal 1 and 2. At present the port uses five tug boats for maneuvering the merchant vessels to berth, two dredgers for maintaining the depth of the quay, four mooring launches, 10 railway locomotives (8 numbers with engine capacity of 700 HP and 2 numbers with 1400 HP). These locomotives are of a hybrid variety, which is mainly operated by the diesel engines, where the transmission of power to the locomotives can be done by making use of a generator.

The specification of all the diesel engines used in the equipment and devices are given in Appendix 6. The diesel consumption by various port owned vehicles, cranes operated at container terminal 1, 2 and equipment are 6.3 million liters/year. Of which 59.2 % and 25.5% of the total diesel consumption is by cranes and tug boats respectively. The diesel consumption by various port owned vehicles and equipment are illustrated in Figure 3.1.
3.1.2 Electricity Consumption Pattern

The major electrical energy consumers in port of Chennai are as follows:

i) Port owned equipment like cranes, pumps, reefer (refrigerated vessels) containers,

ii) Private operated cranes for container movement, transfer cranes for intermodal transportation of containers and

iii) Housing colony.

The major equipment used for energy audit are given in Appendix 7.

The electrical energy consumers in the port of Chennai are shown in Figure 3.2. As electrical energy is considered as high grade energy, it is used
in versatile applications such as lighting, air conditioning of buildings and for powering the cargo handling equipment. Electric cranes on the quays are used mainly for handling dry bulk cargo and are occasionally used for dredging along berths in order to salvage the cargo that has slipped/spilled along the berth in the course of handling. The total electricity consumption in the port of Chennai including port owned equipment, port tenants/user operated equipment and the electrical energy consumed by housing colony is accounted as 25 GWh/yr and the split up is illustrated in Table 3.1. The electricity consumption by the port owned equipment alone is 5.65 GWh/year (22.61% of the total electrical energy consumption). The energy consumption by the port tenant/users due to operation of cranes for container movement and transfer cranes for intermodal transportation of containers in container terminal 1 and 2 accounted for 16.55 GWh/yr. The electrical energy consumed in the housing colony are due to lighting, air conditioning and other home appliances accounted for 2.8 GWh annually.

**Figure 3.2 Major Electrical Energy consumers at Port of Chennai**
Table 3.1  Major Electrical consumption equipment/utilities at port of Chennai

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Electrical consumption (MWh/yr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port owned motors for crane operation</td>
<td>2,092</td>
</tr>
<tr>
<td>Port owned pumps</td>
<td>2,035</td>
</tr>
<tr>
<td>Port owned lighting, HVAC &amp; other loads</td>
<td>1,526.6</td>
</tr>
<tr>
<td>Container terminal 1</td>
<td>8,297</td>
</tr>
<tr>
<td>Container terminal 2</td>
<td>6,511</td>
</tr>
<tr>
<td>Other port users</td>
<td>1,748</td>
</tr>
<tr>
<td>Housing colony</td>
<td>2,796</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>25,005.6</strong></td>
</tr>
</tbody>
</table>

3.2  GHG INVENTORIES

The carbon footprint of the port of Chennai was estimated for the year 2014-15 by applying ISO Standard 14064-1 and WPCI guidelines (WPCI, 2010). These guidelines provide methodologies to evaluate carbon footprints. The direct emissions (scope 1), indirect emissions (scope 2) and the other indirect emissions by port tenants and users (scope 3) have been considered in the assessment. Other indirect emissions accounted in scope 3 include emissions from the fishing harbor and housing colony, which are managed by the port of Chennai. The GHG inventory approach followed in the present work is depicted in Figure 3.3.
Figure 3.3 GHG inventory approach – An overview
3.2.1 Scope 1 Emissions

The scope 1 emissions include diesel fuel usage by transportation, the operation of port owned fleet vehicles (tugs, dredgers, pilot and mooring launches), electricity generation by diesel generators and material handling equipment such as cranes and fork lift trucks. The emissions estimated using Equation (3.1) is based on port activities as per the guidelines of WPCI (WPCI, 2010) and the report on “Guidance for Voluntary Corporate Greenhouse Gas Reporting (2016). The emission factor (EF) for diesel fuel consumption used is 2.68 kg of CO\(_2\)-e / liter.

\[
Emissions = \sum_{i=1}^{n} (Diesel consumption)_i \times EF
\]  

(3.1)

In Equation (3.1) ‘n’ is the number of diesel consuming equipment.

3.2.2. Scope 2 Emissions

The scope 2 emissions are evaluated based on the purchased electricity for the operation of port owned equipment such as cranes, pumps, reefer (refrigerated vessels) containers, machineries in workshop and for building air conditioning, lighting and other uses. Based on the sources of electricity generation in Tamil Nadu and the generation quantity, the emission factor for end user consumption is estimated as 1.13 kg CO\(_2\)-e/kWh (cBalance, 2016). This value is attained by considering the import/export of electricity (0.95 kg CO\(_2\)-e/kWh) and Aggregate Technical and Commercial (AT&C) losses (0.18 kg CO\(_2\)-e/kWh). The scope 2 emissions estimation uses an activity based approach and is given by Equation (3.2).

\[
Emissions = Electrical Energy Consumption \times EF
\]  

(3.2)
3.2.3. **Scope 3 Emissions**

The scope 3 includes several large categories of emissions that contribute to the greatest portion of emission inventory. These categories include the electricity and diesel consumption for privately operated cranes and other wharf equipment, diesel used in fishing harbour, and electricity consumption in ice factories. The emissions due to merchant vessel operations inside the port, truck movements for intermodal transportation of cargo, the use of liquefied petroleum gas (LPG), plus power and petrol use in the port’s housing colony also contribute to scope 3 emissions. The GHG emissions due to various port activities are depicted in the Figure 3.4.

![Figure 3.4 Emission Sources in Ports.](image)

Merchant vessel auxiliary engines are operated in the port to provide electricity to the ships and to power the ship cranes for material handling thus contributing to emissions. Most of these ships have one or more
boilers that are used for fuel heating and producing hot water or steam. A hybrid approach is used to estimate GHG emissions from merchant vessels, based on WPCI guidelines (WPCI, 2010). In this inventory, the emissions from sea transit are not considered and only the emissions from maneuvering and berth hoteling within the boundary of the port of Chennai are considered. Anchorage hoteling is not considered as few merchant vessels are subjected to anchorage hoteling in the port of Chennai. During the maneuvering phase, the emissions from main vessel engine are estimated based on Equation 3.

\[
Emissions = \sum_{i=1}^{n} \left( MCR \times LF \times \text{operating duration} \right) \times EF
\]

(3.3)

In Equation (3.3), \( n \) denotes the number of merchant vessels, MCR is the engine’s maximum continuous rated power in kW, and LF is the Load Factor.

The load factor is the ratio of engine’s power output at a given speed to the engine’s MCR power and it is estimated based on the propeller law and the respective equation is estimated using Equation (3.4).

\[
LF = \left( \frac{\text{Manoeuvring speed}}{\text{Ship maximum speed}} \right)^3
\]

(3.4)

The main vessel MCR and maximum rated speed are obtained based on the world fleet averages, per WPCI guidelines (2010). The maneuvering speed of merchant vessels within the boundary of the port of Chennai is 4 knots. The operating time or maneuvering time is taken as the sum of pre-birth time and outward navigation time. These data are obtained from the Chennai port authorities. It is assumed that the average manufacturing year of the merchant vessels that visited the port of Chennai in
the financial year 2014 - 2015 is 2000 or newer and use medium speed direct drive propulsion. Vessels are assumed to operate their main engines on residual oil (RO), an intermediate fuel oil (IFO 380), or one with similar specifications and an average sulphur content of 2.7%. The assumed GHG emission factor is 0.69 kg CO$_2$e/kWh, based on the IVL, the Swedish Environmental Research Institute study (IVL, 2004). The emissions from vessel auxiliary engine and boiler during the maneuvering phase are estimated using Equation (3.5). The details of auxiliary engine and boiler capacity are obtained from POLA (Port of Los Angeles 2012) inventory of air emissions.

\[
Emissions = \sum_{i=1}^{n} (AS \times Act \times EF)_{i}
\]

(3.5)

In Equation (3.5), ‘i’ corresponds to an operating auxiliary engine or boiler, AS is the auxiliary system (engine or boiler capacity) in kW, ‘n’ denotes the number of AS in operation, Act is the operating/maneuvering time (hours).

The maneuvering time is same as that of used to estimate the GHG emissions from main engine during maneuvering. The emission factor for the auxiliary engine (692.8 g CO$_2$e/kWh) and boiler (994.8 g CO$_2$e/kWh) are based on IVL (2004) and the Euro NATO Training Engineer Center (ENTEC) emission factor for steam boilers (ENTEC, 2012) respectively. During the hoteling phase, the main engine is turned off and only the auxiliary engines and boilers are used. The GHG emissions during the hoteling phase are estimated based on Equation (3.6), with the operating time signifying the time at berth. The berth time for all merchant vessels visiting the port of Chennai was provided by the port authority and was used to obtain the GHG emissions. Emissions from on-road vehicles include the emissions mostly
from trucks. Since the details regarding the fuel consumption of non-port owned trucks used for transporting cargo are not available, a surrogate is used to estimate GHG emissions (shown in Equation (3.6). As per WPCI guidelines for heavy duty vehicles such as trucks, an emission factor of 4.6 kg CO$_2$e/h is estimated for idling periods while 1.0 kgCO$_2$e/km is used for on-terminal running activities (WPCI 2010).

In Equation (3.6), ‘N’ is the number of vehicles, ‘i’ is the counter for vehicles and EF is the emission factor (either kgCO$_2$e/h or kgCO$_2$e/km).

Other scope 3 emissions from sources such as vehicles used for employee transportation and LPG consumption in the housing colony are calculated based on the activity, given in Equation (3.1) with the emission factors for the various fuels consumed obtained from WPCI guidelines (WPCI 2010).