Environmental Ship Index (ESI)
AN INSTRUMENT TO MEASURE A SHIPS’ AIR EMISSION PERFORMANCE

"With regard to air emissions some ships have a better environmental performance than others. Ports want to be able to make the difference."
1. INTRODUCTION
Climate change is very likely due to increased greenhouse gas concentrations in the atmosphere. Transport through ports and port operations are a source of greenhouse gas emissions and therefore contribute to this. Furthermore, stricter air quality standards and concern for nearby residents prompt port authorities to take additional measures to improve the air quality in their ports.

Fifty-five of the world’s key ports have committed themselves reducing their greenhouse gas emissions (GHG) while continuing their role as transportation and economic centres. This commitment is called the World Port Climate Initiative (WPCI, www.wpci.nl). One of the missions of WPCI is to initiate actions to reduce GHG emissions and improve air quality in the shipping sector.

One of the projects within WPCI is the development of an Environmental Ship Index (ESI). The ESI identifies seagoing ships that go beyond the current standards in reducing air emissions. Up to now, it was not possible to identify these ships in a general way. The index is intended to be used by ports to promote clean ships, but can also be used by shippers and ship owners as a promotional instrument. Finally all stakeholders in maritime transport can use the ESI as a means to improve their environmental performance and as an instrument to reach their sustainability goals. The advantages for all potential users are depicted in Figure 1.

THE MAIN CHARACTERISTICS OF THE ESI
- It is a voluntary system, helping to improve the environmental performance of maritime shipping.
- ESI is an instrument to distinguish ships in their environmental performance regarding air pollutants and CO2.
- The ESI gives points for the performance of ships compared to the current international legislation (mainly IMO).
- ESI only takes the NOx and SOx emissions directly into account and awards documentation and management of the energy efficiency. PM10 is indirectly included because of its strong relationship to SOx.
- ESI can be applied to all types of ships.
- ESI is simple in its approach and presentation.
- ESI is easy to establish and to obtain for every ship.

In 2010 the ESI will be introduced and from then its ship database, administrated by IAPH will be filled. It is expected that as from 2011 the ESI will be used by ports to promote clean shipping.

2. ENVIRONMENTAL SHIP INDEX (ESI)
The ESI should ideally reflect all relevant emissions to the air that are important from an environmental and health point of view, including CO2, NOx, PM10 and SOx. At the same time, the ESI should be undisputable and based on current indi-
cators, broadly supported by IMO and available certificates. Research by the Dutch consultancy CE Delft has shown that CO\textsubscript{2} and PM\textsubscript{10} cannot directly be incorporated into the ESI from the start, because there is no reliable certified data available for most of the ships. Energy efficiency indexing has been put on the agenda by IMO recently, but no indicator is available at the moment. PM\textsubscript{10} emissions from maritime engines are not certified by IMO yet. Therefore, no certified data is available about the actual PM\textsubscript{10} emissions of maritime engines. Including PM\textsubscript{10} emissions would be difficult and costly at the moment. Taken the availability of useful indicators and IMO engine certificates into account, an index can currently be based on engine NO\textsubscript{x} emission and the sulphur content of the different fuels used.

With respect to climate emissions, the IMO has put forward guidelines for the voluntary use of an Energy Efficiency Operational Indicator (EEOI)\textsuperscript{1} and the Ship Energy Efficiency Management Plan (SEEMP)\textsuperscript{2}. Both aim for an improvement of the energy efficiency of sea going ships. The ESI will give points for the use of one of both guidelines by operators.

3. ESI FORMULAS
The overall ESI formula is built up of different parts for NO\textsubscript{x}, SO\textsubscript{x} and CO\textsubscript{2}. The weight of the ESI_NO\textsubscript{x} in the overall index is twice the weight of ESI_SO\textsubscript{x}. This reflects the fact that the average environmental damage from NO\textsubscript{x} in ship air emissions is approximately twice the damage from SO\textsubscript{x}. The overall ESI ranges from 0 for a ship that meets the environmental performance regulations in force to 100 for a ship that emits no SO\textsubscript{x} and NO\textsubscript{x} and reports or monitors its energy efficiency.

By comparing the actual performance of a ship with a baseline set, the ESI points can be defined. The baselines are based on the IMO regulations in force, apart from fuels used at berth, where local EU regulation is used.

The index gives a relatively higher weight on emissions at berth and in the ECA, as these have a larger environmental and health impact in and near the ports. The formula for the index is:

\[
ESI_{\text{index}} = \frac{1}{3.1} \left( 2 \times ESI_{\text{NOx}} + ESI_{\text{SOx}} + RR_{\text{CO2}} \right)
\]

Where:
- ESI_NO\textsubscript{x} is the environmental ship index for NO\textsubscript{x}.
- ESI_SO\textsubscript{x} is the environmental ship index for SO\textsubscript{x}.
- RR_CO\textsubscript{2} is the reward for reporting on ship energy efficiency based on the EEOI or a SEEMP.

The ESI_NO\textsubscript{x} and ESI_SO\textsubscript{x} both range from 0 to 100. The weight of the ESI_NO\textsubscript{x} in the overall index is twice the weight of ESI_SO\textsubscript{x}. This reflects the fact that the average environmental damage from NO\textsubscript{x} in ship air emissions is approximately twice the damage from SO\textsubscript{x}. For energy efficiency reporting (RR_CO\textsubscript{2}) the additional score is 10 points. The total amount of points to be scored is 310.

ESI_NO\textsubscript{x}
The ESI_NO\textsubscript{x} indicates the reductions of NO\textsubscript{x} emissions per unit of power below IMO limit values. It covers all engines and weights them according to rated power.

ESI_NO\textsubscript{x} is defined as:

\[
ESI_{\text{NOx}} = \frac{100}{\sum_i P_i} \sum_i \frac{(NO_x\text{ limit value}_i - NO_x\text{ rating}_i) \times P_i}{NO_x\text{ limit value}_i}
\]

Where:
- \( P_i \) is the rated power of engine i.
- \( NO_x\text{ rating}_i \) is the certificated NO\textsubscript{x} emissions of engine i in g/kWh.
- \( NO_x\text{ limit value}_i \) is the maximum allowable NO\textsubscript{x} emissions for an engine with the speed of engine i.
- \( n \) number of engines.

ESI_NO\textsubscript{x} can be unequivocally calculated using the EIAPP certificates of the engines on board a ship. Ships that do not have an EIAPP onboard can not obtain points for ESI_NO\textsubscript{x}.

ESI_SO\textsubscript{x}
The ESI_SO\textsubscript{x} reflects the reduction in sulphur content of the fuels below the limit values set by IMO and regional authorities. Three types of fuel are distinguished: fuels typically used at high seas, fuels typically used in ECAs and fuels typically used at berth. The baselines are based upon IMO limit values and will be tightened in accordance with IMO limits. ESI SO\textsubscript{x} gives higher weighting to the fuels used in ECAs and at berth, due to its greater impact on the ports and its surrounding areas.

\textsuperscript{1} MEPC.1/Circ.684, \textsuperscript{2} MEPC.1/Circ.683 \textsuperscript{3} NO\textsubscript{x} emissions are roughly twice the SO\textsubscript{x} emissions per unit of work, with damage costs being in the same range.
4. IMO ANNEX VI REGULATIONS AND ESI BASELINES

Sulphur

In the next years the lowered limits for fuel sulphur content from the revised Annex VI to the MARPOL Convention will come into effect, as indicated in Table 1.

Table 1  MARPOL Annex VI Sulphur Limit in Fuel

<table>
<thead>
<tr>
<th>Date</th>
<th>Sulphur Limit in Fuel (% m/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High sea</td>
</tr>
<tr>
<td>2005</td>
<td>4.5%</td>
</tr>
<tr>
<td>2010, July</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>3.5%</td>
</tr>
<tr>
<td>2015</td>
<td></td>
</tr>
<tr>
<td>2020a</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

a - alternative date is 2025, to be decided by a review in 2018

The baselines of ESI are in line with the above presented IMO sulphur limits. This implies that at the date the IMO fuel sulphur limits will be tightened, the ESI baseline will be adjusted as well. The EU Marine Fuel Sulphur Directive (2005/33/EC), that enforces the use of 0.1%S fuel as from 1st January 2010, will be used as a baseline from that date on.

Table 2  Set of SO₂ baselines

<table>
<thead>
<tr>
<th>Date</th>
<th>Sulphur Limit in Fuel (% m/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High sea</td>
</tr>
<tr>
<td>2009</td>
<td>4.5%</td>
</tr>
<tr>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>2010, July</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>3.5%</td>
</tr>
<tr>
<td>2015</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

Nitrogen oxides

MARPOL Annex VI also limits the NOₓ emissions of future marine engines. Figure 2 depicts the emission limits for current and future Tiers. The limit value depends on the rated engine speed above 130 rpm.
5. DATA NEEDED FOR ESI CERTIFICATION

To calculate the ESI points of a ship, the information needed is summarized in Table 3.

Table 3  Data needed for ESI calculation

<table>
<thead>
<tr>
<th>Document</th>
<th>ESI NOₓ</th>
<th>ESI SOₓ</th>
<th>RR_CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power (kW)</td>
<td>EIAPP certificate</td>
<td>Bunker delivery notes over 1 year</td>
<td>EEOI reporting or ship energy efficiency management plan</td>
</tr>
<tr>
<td>RPM and speed (rpm) main engine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated power (kW)</td>
<td></td>
<td>Average fuel sulphur content per bunkering per kind of fuel (%)</td>
<td></td>
</tr>
<tr>
<td>RPM and speed (rpm) auxiliary engines</td>
<td></td>
<td>Amount of fuel, per kind of fuel, bunkered per delivery (ton)</td>
<td></td>
</tr>
<tr>
<td>Actual NOₓ emission value (g/kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To calculate the ESI NOₓ, the IMO limit value for a particular engine needs to be compared with the engine's actual certified value. This information is documented in the engine International Air Pollution Prevention (EIAPP) certificate. This certificate has been issued since 2000 for all engines that meet the IMO Tier I standard. Ships that do not have these certificates available can not apply for ESI NOₓ.

Abatement technologies:
The NOₓ and SOₓ input for the ESI can be adjusted for IMO approved abatement technologies (like scrubbers and Selective Catalist Reduction) in accordance with the emitted equivalent SOₓ and NOₓ emissions.
6. EXPERIENCES WITH ESI CALCULATION
The WPCL working group developed a questionnaire that was distributed under ships by different ports in a field test. The data presented in Table 3 was gathered from a sample of 50 ships and on that basis the ESI points for the ships were calculated. On the basis of the current baselines and the formulas ESI points were calculated. The field test has shown that:
- The approach chosen is feasible and the data are available onboard of ships.
- The time needed to gather the data and calculate ESI points is limited to 2-4 hours per ship once a year.
- The environmental performance and hence ESI points of ships show significant difference. On average, Tier I main engines emit on average 80% of the permitted emissions. Auxiliary engines emit on average 90% of the permitted level. However the range was between 60 and 100% of the Tier I standard.

- The difference in sulphur contents varies significantly on the high sea, reflecting the difference in fuel sulphur contents in different parts of the world. Also at berth, the sulphur contents vary due to the use of both gasoil and heavy fuel oil at the moment. As from 2010, the differences will be limited. In the ECAs, the sulphur content of most fuels are close to the 1.5% S limit.

In Figure 3, the ESI points for a sample of ships are depicted on the basis of baselines for 2009. For more information see CE, 2009b.

As can be seen from Figure 3 the difference between ships is relatively big, reflecting the difference in NOx emissions of the engines and fuel sulphur contents of the fuels used.

Note: On the y-axis the identification numbers of the questionnaires are listed. Energy efficiency reporting was not included in the questionnaire, and is therefore not included in these points.

7. ESI CALCULATION EXAMPLE
Below, we provide an example of ESI calculation for a specific ship. The ship in the example has one main engine and three auxiliary engines. The ship uses all three types of fuel. The calculations are based on baselines that apply after July 2010. The formulas and baselines are depicted in section 3 and 4.

**Sulphur**
The average sulphur content of the different fuels is extracted from the bunker delivery notes. The average for the respective fuels is the weighted average over all bunkers. The use of fuels that are under the respective baselines is the only criterion for ESI points. This implies that whenever a ship can demonstrate the use of a certain fuel, it will be settled against this.
For the different regions, the relative improvement compared to the baselines is awarded, as presented in section 3 and 4:

\[
\frac{4.5 - 2.0}{4.5} \times 30 + \frac{1.0 - 0.5}{1.0} \times 35 + \frac{0.1 - 0.08}{0.1} \times 35 = 17 + 17 + 7 = 41
\]

### Nitrogen oxides

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Tier I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowed emission level (IMO Annex VI)</td>
<td>17 g/kWh</td>
</tr>
<tr>
<td>Actual emission level</td>
<td>15 g/kWh</td>
</tr>
<tr>
<td>Power</td>
<td>9.48 MW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Auxiliary engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowed emission level (IMO Annex VI)</td>
</tr>
<tr>
<td>Actual emission level</td>
</tr>
<tr>
<td>Power</td>
</tr>
<tr>
<td>Number</td>
</tr>
</tbody>
</table>

\[
\left(\frac{(17-15) \times 9480}{17} + \frac{(11.5-11) \times 970 \times 3}{11.5} \right) + \frac{1}{9480 + 970 \times 3} \times 100 = 10
\]

### EEOI reporting or ship energy management plan

The ship has an energy management plan. This generates 10 additional points.

### Overall ESI

For this example the overall ESI points are as follows:

\[
2 \times \frac{10}{3.1} + \frac{41}{3.1} + \frac{10}{3.1} = 23
\]

8. ADMINISTRATION AND VERIFICATION

**Administration**

The administration of ESI is carried out by the ESI bureau that is part of IAPH.

**Activities of the ESI bureau**

- Confirming receipt of self declarations (SDs) of ships regarding their ESI index.
- Cross checking application of formulas and data used in the ESI self declaration (SD) and verify appropriate consequent issuance of index points. A web based tool shall automatically establish the ESI points. The number of points is inextricably connected to a particular ship and will remain available for such ship.
- Informing the applicant owner/ship of the results of the cross check and issuance of a certificate. Showing the total points
- Making available on the user’s (ports, terminals, shippers) non-public section of the ESI website ships data such as:
  - Name.
  - IMO identification number.
- Owner/operator/manager.
- Verified number of ESI Points (including distribution over the parameters).
- Period of validity of such points.
- Number of years in the system.
- Making available on the public section of the website, a description of the system in a general form, the names of the ships that have submitted a SD and providing such data on the incentives systems as has been authorized by the organizations that provide such incentives.

**Rules & Conditions**

- The self declaration (SD) should contain at least a statement to the effect that the owner/operator/manager of a ship, in submitting the self declaration to the ESI bureau, agrees to the conditions for including the ships details regarding ESI in the ESI Bureau's database and the consequent dissemination of such data at the request of and to such ports that are participating in the ESI system, as laid down in the ESI Rules and Conditions as published on the ESI website.
- The data of the SD should be provided on an annual basis in an electronic form and the documents pertaining thereto should be kept on board the vessel for a period of at least two years.
- The ship may be subject to an inspection on the correctness of the self declaration and the data used in the ESI formulas by any incentive provider that includes that ships in its participation in the scheme, at the sole discretion of that provider. The results of such inspection should be transmitted to the ESI administration to be available for the users.
- An incentive provider is considered to be participating in the ESI scheme if it has informed the Board of ESI of its intentions, based on the ESI points as laid down by the ESI administration. If no such information has been received the data base system cannot be accessed.

**Finance**

Payment of a contribution to the ESI administration for costs connected with the entry into the system is now being discussed. If it would be so decided it is envisaged that the amount would not exceed € 400,00 per ship (incl. VAT) which would be payable before entering data for any ship into the ESI database.

Such a fee would be valid for a period of 5 years and cannot be reimbursed and would include regular updates where applicable.