Carlo Trozzi
Emission Inventorying in Italian Ports

17th JOINT EIONET AND UNECE TASK FORCE ON EMISSION INVENTORIES AND PROJECTIONS MEETING
Transport Expert Panel
16th May 2016, Zagreb, Croatia
topics

- Italy case studies
- $\mathcal{E}^2$Port Model
- Emissions estimate Methodologies
- Case studies results
  - Emissions
  - Controls
  - Costs
- Challenges of port cities
Italy case studies

**Liguria Region study**
- Focus on all emissions sources (ships maneuvering and hoteling and land based operations) in port environment (Genoa, La Spezia, Savona)

**National feasibility study for cold ironing**
- Involves four national ports (Livorno, Ravenna, Gioia Tauro, Taranto) and a cruise line with three cruise terminals (Palermo, Napoli, Livorno) in the Tyrrhenian Sea

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**Carlo Trozzi**

*Emission Inventoring in Italian Ports*
Ports in national study

Livorno Li, Italia

Napoli Cruise Terminal

Palermo Cruise Terminal

Taranto TA, Italia

Gioia Tauro

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Emission Inventorying in Italian Ports
Ports in Liguria Study

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\$E^2\text{Port}\$ Model

\$E^2\text{Port}\$ is a comprehensive model to assess consumption and environmental impacts of ship activities in port and at sea. The model evaluates in the port area:

- Emissions of air pollutants
- Fuel consumption and emissions of carbon dioxide
- Emissions of air pollutants from ground support equipment
- Fuel consumption and emissions of carbon dioxide from ground support equipment
- Emissions of air pollutants from general road traffic
- Fuel consumption and emissions of carbon dioxide from general road traffic
- Emissions to air from other port activities (materials handling, fuel handling, ship repair)
E2Port model allows to manage:

- database of ships movements (IMO ship code, ship name, dock of berth, time of berth, time of departure, time of leave from the port)

- database of other port activities:
  - amount petroleum products handled in port
  - amount of solid fuels handled
  - amount of other pulverulent material handled
  - fuel consumption of land based service vehicles
  - number of cars and light and heavy commercial vehicles entering the port to board
  - amount of coating and solvent used for the maintenance of ships (in particular coating of the surface preparation and related activities).

- database of emission factors including all the emission factors needed for estimating emissions.
Emissions Estimate Methodology

- Evaluation of time spent by ship in each operation of hoteling by dock and, for Liguria study, of manoeuvring (1 to 4 years data)
- Ships fuel consumptions evaluation and emissions estimate by dock, ship, and ship operation
- In Liguria study, data retrieval and emissions estimate from land based activities (oil product loading/unloading, dry dock activities, aggregate handling and storage, service vehicles handling, vehicles in transit)
Ships fuel consumptions and emissions

- For every berth, at each port, date and time of arrival and departure of each ship have been collected.
- Single ship specific fuel consumptions has been evaluated from ship’s engines power (*Lloyd’s Register of ships* and direct census on national ships).
- Fuel consumptions $C_{ijk}$ and emissions $E_{ijkl}$ at berth and manoeuvring (only Liguria) have been computed as:
  
  \[
  C_{ijk} = P_{jk} \cdot L_{jk} \cdot t_k \cdot FC_{ijk} \\
  E_{ijkl} = C_{ijk} \cdot F_{ijkl}
  \]

  - $i$, fuel (Bunker Fuel Oil, Marine Gas Oil); $j$, type of engine (main, auxiliary); $k$, phase (berth, manoeuvring); $l$, pollutant
  - $P_{jk}$, power; $L_{jk}$, load; $FC_{ijk}$, specific fuel consumption; $t_k$, time spent in the specific phase; $F_{ijkl}$, emissions factor.
Ship Engines operation parameters

<table>
<thead>
<tr>
<th></th>
<th>% load of MCR for ME operation</th>
<th>% of time all MEs operating</th>
<th>% of electric power from shaft generators</th>
<th>% load of MCR* for AE operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>At sea</td>
<td>80</td>
<td>100</td>
<td>50-100***</td>
<td>0***-30</td>
</tr>
<tr>
<td>In port (tankers-using pumps)</td>
<td>20</td>
<td>100</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>In port (no tankers)</td>
<td>20</td>
<td>5</td>
<td>0</td>
<td>0***-30**-40</td>
</tr>
<tr>
<td>Manoeuvring in port</td>
<td>20</td>
<td>100</td>
<td>0</td>
<td>0***-50</td>
</tr>
</tbody>
</table>

** Data from survey in this study, Entec, 2005 otherwise
*** Turbine electric propulsion, Diesel propulsion otherwise

Ships Specific fuel consumptions

<table>
<thead>
<tr>
<th>Engine type</th>
<th>Specific fuel consumptions (g/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bunker Fuel Oil (BFO)</td>
</tr>
<tr>
<td>High-speed diesel</td>
<td>234</td>
</tr>
<tr>
<td>Medium-speed diesel</td>
<td>234</td>
</tr>
<tr>
<td>Slow-speed diesel</td>
<td>215</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>336</td>
</tr>
<tr>
<td>Steam turbine</td>
<td>336</td>
</tr>
</tbody>
</table>

Emission Inventorying in Italian Ports
## Ships emissions factors

<table>
<thead>
<tr>
<th>Engine type</th>
<th>Bunker Fuel Oil (BFO)</th>
<th>Marine Gas Oil (MGO)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO&lt;sub&gt;x&lt;/sub&gt; (g/kWh)</td>
<td>PM&lt;sub&gt;10&lt;/sub&gt; (g/kWh)</td>
</tr>
<tr>
<td>High-speed diesel</td>
<td>9,30</td>
<td>2,40</td>
</tr>
<tr>
<td>Medium-speed diesel</td>
<td>10,80</td>
<td>2,40</td>
</tr>
<tr>
<td>Slow-speed diesel</td>
<td>14,00</td>
<td>2,40</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>3,00</td>
<td>1,50</td>
</tr>
<tr>
<td>Steam turbine</td>
<td>1,60</td>
<td>2,40</td>
</tr>
</tbody>
</table>

### Auxiliary engines

| Medium-speed diesel    | 14,20                 | 0,80                  | 0,40          | 13,50                 | 0,30                  | 0,40          |

Oil product loading/unloading

Monthly VOCs emissions are estimated on each dock using the amount of product handled (crude oil, diesel, gasoline), obtained from ports operators, and VOCs emission factors (US EPA, 2008) taking into account control systems (if used) and, for gasoline, temperature and fuel volatility (Concawe, 2009)

Dry dock activities

Painting and related activities of surface preparation monthly VOCs and PM emissions are estimated by multiplying the amount of product used (paint, degreasing, abrasive) for appropriate emission factors for painting (EMEP / EEA, 2009), degreasing (EMEP / EEA, 2009), and abrasion (US EPA, 1997)
Aggregate handling and storage
(loadin and unloading and wind erosion)

- $PM_{10}$ and $PM_{2.5}$ emissions from handling of solid fuel and other pulverulent materials estimated as a function of disturbance events occurrence, wind and characteristics of the products (US EPA, 2006)

- $PM_{10}$ and $PM_{2.5}$ emissions from by wind erosion:
  - each time that a pile of material is disturbed a certain amount of volatile material is to be found on the surface of the pile and thus can be removed by wind
  - emissions are not continuous but occur for events characterized by wind speed above a certain threshold
Service vehicles handling

- For service vehicles to port activities, the estimate of emissions is done by multiplying the fuel consumption (census on operators) for appropriate emission factors (EMEP/EEA Guidebook, 2013).

Vehicles in transit in port area

- For the movement of cars and light and heavy commercial vehicles on the roads inside the port area, emissions estimate is done by multiplying the distance traveled by vehicles in the port area to the regional average pollutants emission factors for different types of vehicles.
Results - NOx Emissions - National study
Results - Liguria regional study emissions

[Bar chart showing emissions for different ports and pollutants]
Emissions control with cold ironing (CI)

Connection of the ships to the land based electric network during their stay in port allowing ships to turn off their auxiliary engines in such a way that all the engines of the ship can be switched off in port.
Cold ironing (CI) emissions reduction

- Reduction of net emissions, because land-based electricity generation complies with emission standards more stringent than those for ship engines.
- Commission of the European Communities published a Recommendation in 2006.
- Emissions reduction are evaluated, with a very conservative approach, comparing emissions from ships with emissions from land-based electricity production from fossil fuels computed with average national emission factors; only ships stops whose duration is greater than a threshold value (2 hours), chosen based on technical times of connection and disconnection, have been taken into account.
Emissions and potential CI reductions
All docks connected - National study

NO\textsubscript{x} emissions reductions are in the range of 80%-95%,
SO\textsubscript{x} reductions are about 35% (respect to 0.1% sulfur content marine fuel oil), for PM\textsubscript{10} are in the range 68%-95% and for NMVOC are in the range 78%-95%
Regione Liguria case study
Genova port on-going and planned measures
Regione Liguria case study
Genova port other possible measures
Regione Liguria case study

Emissions with all reductions
Techno-economic aspects of cold ironing (national study)

- No major technical or economic issue, which may constitute obstacles to the development of actions at individual docks, has been detected.

- A land-based power source, transmission system, and related infrastructures are required to provide electricity to a hotelling marine ship.

- An electrical cable system is required to bring shore-side power to the ship during hotelling.
**Electrical loads in port (national study)**

The electrical loads required for each dock and globally for the whole port have been evaluated.

<table>
<thead>
<tr>
<th>Port</th>
<th>Average power (kW)</th>
<th>Maximum power (kW)</th>
<th>95° percentile (kW) (*)</th>
<th>90° percentile (kW) (**)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taranto</td>
<td>10.758</td>
<td>24.669</td>
<td>17.081</td>
<td>15.391</td>
</tr>
<tr>
<td>Livorno</td>
<td>21.739</td>
<td>86.243</td>
<td>40.850</td>
<td>33.830</td>
</tr>
<tr>
<td>Palermo cruise terminal (****)</td>
<td>11.049</td>
<td>49.522</td>
<td>32.690</td>
<td>28.385</td>
</tr>
<tr>
<td>Napoli cruise terminal (*****)</td>
<td>15.533</td>
<td>36.190</td>
<td>34.613</td>
<td>30.160</td>
</tr>
</tbody>
</table>

(*) 95% hours/year maximum total power requirements less than the reported value
(**) 90% hours/year maximum total power requirements less than the reported value
Money saving with cold ironing vs. oil prices (national study)

in the cost/benefit analysis it is used the forecast of 344€/t for MGO (1% sulfur content) in 2020 (Concawe, 2009) evaluating the impact of taxes

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Cost benefit analysis
(national study)

<table>
<thead>
<tr>
<th>Port</th>
<th>Cost effective (€/Mg) VAT not included</th>
<th>Cost effective (€/Mg) VAT not included</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO\textsubscript{x} Sum of NO\textsubscript{x}, SO\textsubscript{x}, NMVOC, PM</td>
<td>NO\textsubscript{x} Sum of NO\textsubscript{x}, SO\textsubscript{x}, NMVOC, PM</td>
</tr>
<tr>
<td>Livorno</td>
<td>7.04 6.26</td>
<td>5.42 4.82</td>
</tr>
<tr>
<td>Ravenna</td>
<td>13.53 12.26</td>
<td>11.86 10.75</td>
</tr>
<tr>
<td>Gioia Tauro</td>
<td>5.74 5.26</td>
<td>4.23 3.88</td>
</tr>
<tr>
<td>Taranto</td>
<td>7.44 6.76</td>
<td>5.94 5.39</td>
</tr>
<tr>
<td>Napoli</td>
<td>5.94 4.87</td>
<td>3.91 3.20</td>
</tr>
<tr>
<td>Palermo</td>
<td>16.51 13.60</td>
<td>14.2 10.00</td>
</tr>
</tbody>
</table>

\[
CE_i = \frac{C}{Er_i}
\]

where: \( i \), pollutant; \( CE_i \) cost effective for the reduction of emissions (€/tonne); \( C \) total cost (€/year); \( ER_i \) reduced emissions of pollutant \( i \) (tons/year)

The table don’t take into account external costs of environmental damage: 6.3 €/tonn for NO\textsubscript{x}, 135.5 for PM, 10.1 for SO\textsubscript{x}, 7.5 for NMVOC (MIRA 2011)

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[Image]
Challenges of port cities

- Often cities have difficulties in complying with the limits imposed by EU legislation on air quality, particularly for the annual average concentration of nitrogen oxides.

- There is a high number of ports in Europe, often with large cruise terminals, that are fully integrated into the city.

- With the progressive reduction of emissions from road traffic and large combustion sources, the impact of the ports in coastal cities becomes increasingly important also in situations where there are on territory large point sources such as power plants.
Genova port (west)
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Genova port NO\textsubscript{x} berth emissions
Genova Municipality
Nitrogen Oxides Emissions

Emission Inventorying in Italian Ports
Air quality modeling

Ships and other sources emissions for Liguria region has been used to input air quality models CHIMERE/CALPUFF.

Emissions are modeled as area emissions; sensitivity study realized about vertical emission profiles for ships.
Conclusions (1)

- Emissions from ships at dock are the most relevant ones (regional study) at regional scale.
- Great potential of cold ironing for reducing emissions, between 750 to 4700 tons per year in port for nitrogen oxides, nearly 400 tons for the largest cruise terminal in the national study (in city centre).
- No major technical obstacles to development of actions.
- Major constraint is the cost that ship-owners will have to face for the adaptation of onboard systems.
- A coordinated European approach to carry out initiatives that allow owners to use the service of "cold ironing" in different ports is a priority.
Conclusions (2)

- A reduced rate of electricity tax applied to electricity directly provided to vessels at berth in a port can give an economic incentive to the use of shore-side electricity [some initiatives in such directions in EC legislation]

- The emissions reductions in port allow to obtain a very important contribute to reduce overall municipal emissions (up to 40% of municipality emissions of nitrogen oxides in regional study)

- Air quality modeling using area source emissions can be insufficient; in the future emissions will be modelled as point sources
acknowledgement

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Some of the results from the work carried out under a contract from Liguria Regional Administration

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