Advanced Cleaner Freight Locomotive Technologies

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Forum 2: Advanced Rail and Truck Technology Development and Deployment

Policy Forum Series
Delivering the Green: The Future of California’s Freight Transportation System
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Needed Pollution Reduction to Meet Ozone Air Quality Standards

- Heavy-Duty Diesel Trucks
- Off-Road Equipment
- Ocean-going Vessels
- Other
- RECLAIM (Large Stationary)
- Locomotives
- Aircraft
- Residential Fuel Combustion
- Heavy-Duty Gasoline Trucks
- Light-Duty Vehicles
- Medium-Duty Trucks
- Light-Duty Trucks
- Manufacturing and Industrial
- Commercial Boats
- Service/Commercial

Needed by 2023
Needed by 2032
Top NOx Emissions Sources in 2023

- Heavy-Duty Diesel Trucks: 51 tons/day
- Off-Road Equipment: 43 tons/day
- Ships & Commercial Boats*: 41 tons/day
- RECLAIM**: 27 tons/day
- Locomotives: 22 tons/day
- Aircraft: 16 tons/day
- Residential Fuel Combustion: 16 tons/day
- Heavy-Duty Gasoline Trucks: 13 tons/day
- Passenger Cars: 15 tons/day
- Med-Duty Gasoline Vehicles: 14 tons/day
- Light Duty Trucks/SUVs: 13 tons/day

* Oceangoing vessels = 32 tons/day
** RECLAIM: 320 largest stationary sources, including all refineries and power plants
## Locomotive Emission Standards

### Line-Haul Locomotive Emission Standards, g/bhp·hr

<table>
<thead>
<tr>
<th>Tier</th>
<th>MY</th>
<th>Date</th>
<th>HC</th>
<th>CO</th>
<th>NOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 0</td>
<td>1973-1992</td>
<td>2010</td>
<td>1.00</td>
<td>5.0</td>
<td>8.0</td>
<td>0.22</td>
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<tr>
<td>Tier 1</td>
<td>1993-2004</td>
<td>2010</td>
<td>0.55</td>
<td>2.2</td>
<td>7.4</td>
<td>0.22</td>
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<tr>
<td>Tier 2</td>
<td>2005-2011</td>
<td>2010</td>
<td>0.30</td>
<td>1.5</td>
<td>5.5</td>
<td>0.10</td>
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<tr>
<td>Tier 3</td>
<td>2012-2014</td>
<td>2012</td>
<td>0.30</td>
<td>1.5</td>
<td>5.5</td>
<td>0.10</td>
</tr>
<tr>
<td>Tier 4</td>
<td>2015 or later</td>
<td>2015</td>
<td>0.14</td>
<td>1.5</td>
<td>1.3</td>
<td>0.03</td>
</tr>
</tbody>
</table>

- Tier 0-2 line-haul locomotives must also meet switch standards of the same tier.
- Tier 3 line-haul locomotives must also meet Tier 2 switch standards.
- 1993-2001 locomotive that were not equipped with an intake air coolant system are subject to Tier 0 rather than Tier 1 standards.
- As early as 2008 if approved engine upgrade kits become available.
- 0.20 g/bhp-hr until (with some exceptions).
- Manufacturers may elect to meet a combined NOx+HC standard of 1.4 g/bhp-hr.

## Locomotive Emission Standards

### Switch Locomotive Emission Standards, g/bhp·hr

<table>
<thead>
<tr>
<th>Tier</th>
<th>MY</th>
<th>Date</th>
<th>HC</th>
<th>CO</th>
<th>NOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 0</td>
<td>1973-2001</td>
<td>2010</td>
<td>2.10</td>
<td>8.0</td>
<td>11.8</td>
<td>0.26</td>
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<tr>
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<td>2002-2004</td>
<td>2010</td>
<td>1.20</td>
<td>2.5</td>
<td>11.0</td>
<td>0.26</td>
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<tr>
<td>Tier 2</td>
<td>2005-2010</td>
<td>2010</td>
<td>0.60</td>
<td>2.4</td>
<td>8.1</td>
<td>0.13</td>
</tr>
<tr>
<td>Tier 3</td>
<td>2011-2014</td>
<td>2011</td>
<td>0.60</td>
<td>2.4</td>
<td>5.0</td>
<td>0.10</td>
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<tr>
<td>Tier 4</td>
<td>2015 or later</td>
<td>2015</td>
<td>0.14</td>
<td>2.4</td>
<td>1.3</td>
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</tbody>
</table>

- Tier 1-2 switch locomotives must also meet line-haul standards of the same tier.
- As early as 2008 if approved engine upgrade kits become available.
- 0.24 g/bhp-hr until (with some exceptions).
- Manufacturers may elect to meet a combined NOx+HC standard of 1.3 g/bhp-hr.

Technologies to Meet Tier 4

- **NOx**
  - Exhaust Gas Recirculation
  - Selective Catalytic Reduction

- **PM**
  - Diesel Oxidation Catalyst
  - Particulate Filters

- Alternative Fuels
Technologies to Go Beyond Tier 4

- Electric
  - Overhead Catenaries
  - Battery/Hybrid

- LNG
  - Potential to go Beyond Tier 4

Source: ge.com
Technologies to Go Beyond Tier 4

- Zero-Emission Concepts
  - Linear Drive Systems
  - Battery Tender Concepts
  - Fuel Cell

Source: GE Presentation, Technology Symposium, April 11, 2013
Source: LEVX Presentation, Technology Symposium, April 11, 2013
Source: www.transpowerusa.com
Other Emission Reduction Opportunities

- “Hood” Technologies
- Grade Separations
Drivers for Deployment of Advanced Rail Technologies

- Reduce Exposure to Emissions from Rail-Related Sources
- Demonstration Programs to Assess Performance
- Policy Direction for Infrastructure Development
- Rail Industry Perspective - “Business” Case
- Public Funding Assistance to Help Offset Additional Cost of Advanced Technologies