Emissions from Motor Vehicles Powered by Liquefied Petroleum Gas in the Republic of Croatia

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- Liquefied Petroleum Gas
- Passenger cars fleet in the Republic of Croatia
- Pilot Study: LPG Vehicles – In Service Emission Test
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Liquefied Petroleum Gas – LPG

- mixture of hydrocarbons, mainly the two gases: propane and butane,
- in the liquid state at room temperature and relatively low pressure,
- liquefaction reduces the volume of gases by factor 250.

Origin:
• crude oil processing (~ 40% of worldwide production),
• crude oil and natural gas extraction (~ 60% of worldwide production).

Markets / Consumers:
• domestic sector (cooking and heating) ~ 50%,
• petrochemical industry,
• transportation only about 10%.

Most widely used alternative fuel:
• low price,
• highly developed supply system,
• easy conversion of existing engines.
Passenger cars fleet in the Republic of Croatia

In year 2015: 1,476,229 passenger cars registered

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>52.95 %</td>
</tr>
<tr>
<td>Diesel</td>
<td>43.18 %</td>
</tr>
<tr>
<td>LPG</td>
<td>3.78 %</td>
</tr>
<tr>
<td>CNG, Hybrid, Electric</td>
<td>0.09 %</td>
</tr>
</tbody>
</table>

Average PC fleet age: 12.52 years
Average LPG PC fleet age: 13.4 years
PC fleet by emission level and fuel type
In Service Emission Test

• Introduced in early ‘80s as part of PTI in some EU member states
• In service emission test provision: Directive 92/55/EEC
• Current Directive 2014/45/EU

In the Republic of Croatia:
• Introduced in 2001 for SI engines
• Introduced in 2002 for CI engines

Passenger cars: periodical technical inspection once a year
In service emission test („EKO-TEST“) obligatory for passenger cars

LPG vehicles are exempt from in service emission test
In Service Emission Test

Visual inspection of exhaust emission control system

Measurements using exhaust gas analyser

- Measurable gases: CO, CO$_2$, HC, O$_2$
- Lambda calculated
- Measuring principle:
  - Infrared spectrometry for CO, CO$_2$, HC
  - Electrochemical detection for O$_2$
- Engine speed
- Engine temperature
- Opacity for CI engines
In Service Emission Test
In Service Emission Test

Fail criteria according to Directive 2014/45/EU

Fail criteria in the Republic of Croatia:

1. Exceeded specific levels given by vehicle manufacturer

2. If manufacturer limit levels not available, emissions exceed:
   - for vehicles without advanced emission control system:
     - CO > 3.5 %, first registration after 1987
     - CO > 4.5 %, first registration 1986 and before
   - for vehicles with advanced emission control system:
     - CO > 0.5 % at engine idle
     - CO > 0.3 % at high idle

3. Lambda outside the range 1± 0.03
Pilot Study: LPG Vehicles - In Service Emission Test

Pilot study:
- In service emission test for LPG powered vehicles
- Sample: 500 vehicles
- Random samples during regular PTI across HR
- Emission test carried out for both fuels: Gasoline and LPG

Pilot study data set:
- Idle: CO, CO$_2$, HC, O2, $\lambda$, $n$, $T_{\text{oil}}$
- High idle: CO, CO$_2$, HC, O2, $\lambda$, $n$, $T_{\text{oil}}$
- Vehicle data: emission level, year, mileage
- Emission limit values

Valid data set for 472 vehicles.
Pilot study vehicle structure by emission level

Total number of tested vehicles: 472

<table>
<thead>
<tr>
<th>Emission level / Stage</th>
<th>Number of vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-Euro &amp; Euro 1</td>
<td>38</td>
</tr>
<tr>
<td>Euro 2</td>
<td>107</td>
</tr>
<tr>
<td>Euro 3</td>
<td>111</td>
</tr>
<tr>
<td>Euro 4</td>
<td>193</td>
</tr>
<tr>
<td>Euro 5</td>
<td>22</td>
</tr>
<tr>
<td>Euro 6</td>
<td>1</td>
</tr>
</tbody>
</table>

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LPG PC fleet in the Republic of Croatia

Fleet: 55,859 vehicles

Emission level / Stage

- pre-Euro & Euro 1: 7,070
- Euro 2: 13,220
- Euro 3: 13,907
- Euro 4: 19,675
- Euro 5: 1,892
- Euro 6: 95
LPG PC and pilot study fleet

**EU emission level**

<table>
<thead>
<tr>
<th>EU emission level</th>
<th>LPG Fleet</th>
<th>Pilot study</th>
</tr>
</thead>
<tbody>
<tr>
<td>pre-Euro &amp; Euro 1</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Euro 2</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>Euro 3</td>
<td>25%</td>
<td>35%</td>
</tr>
<tr>
<td>Euro 4</td>
<td>40%</td>
<td>45%</td>
</tr>
<tr>
<td>Euro 5</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>Euro 6</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Pilot study vehicle age

Total number of tested vehicles: 472

Average age: 13.1

Number of vehicles

Vehicle age
Pilot study vehicle mileage
Overall results

Average 42.3 % LPG PC failed

Complete PC fleet: 6.6% failed

Emission level

Euro 5 & 6  Euro 4  Euro 3  Euro 2  Euro 1

Vehicles failed technical inspection, %

LPG  Gasoline  Without fuel influence
Overall results - failures

Number of failures

- Max CO at idle speed
- Max CO at fast idle speed
- Lambda

Failure types:
- LPG
- Gasoline

Graph showing the number of failures for various failure types at idle and fast idle speeds, compared between LPG and Gasoline fuels.
Overall results – CO idle emission

<table>
<thead>
<tr>
<th>Category of CO values, %</th>
<th>LPG</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05 &gt; CO ≤ 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1 &gt; CO ≤ 0.2</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>0.2 &gt; CO ≤ 0.3</td>
<td>226</td>
<td></td>
</tr>
<tr>
<td>0.3 &gt; CO ≤ 0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4 &gt; CO ≤ 0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;0.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EU limit
HR limit

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Overall results – CO high idle emission

Number of vehicles

<table>
<thead>
<tr>
<th>Category of CO values, %</th>
<th>LPG</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 0.05</td>
<td>222</td>
<td>187</td>
</tr>
<tr>
<td>0.05 &gt; CO ≤ 0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.1 &gt; CO ≤ 0.2</td>
<td>104</td>
<td>108</td>
</tr>
<tr>
<td>0.2 &gt; CO ≤ 0.3</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>0.3 &gt; CO ≤ 0.4</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>0.4 &gt; CO ≤ 0.5</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>&gt; 0.5</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

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Conclusions

Passenger cars fleet: 1,476,229 vehicles
Average PC fleet age: 12.52 years
In 2015 in service emission test 6.61% of PC fleet failed.

LPG PC fleet: 55,859 vehicles
Average LPG PC fleet age: 13.4 years
Pilot study fleet: 472 vehicles
Pilot study average age: 13.1 years
In service emission test failed by 42.3% of pilot study fleet.
LPG vehicles have more than 6 time higher failure rate then average PC fleet.

In service emission test should be mandatory for LPG vehicles.
Thank you for your attention!

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