Quantification of Energy Consumption and Emissions using Biodiesel in an Urban Bus Fleet

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Bioenergy: From Concept to Commercial Production
March, 8th, 2006
Our Mission

DTEA is a research team dedicated to innovation in the area of Transports, Energy and Environment through the development, transfer and dissemination of scientific and technological knowledge.
Our position within IST

IDMEC
Instituto de Engenharia Mecânica Pólo IST

Research Group on Energy and Sustainable Development

Main Research Areas

**Energetic Consumptions and Pollutant Emissions**
- Energetic and Environmental Evaluation
- Management of Fleets
- Auditorships
- Monitorization

**Sustainable Mobility**
- Mobility Strategies
- Public transport nets
- Sustainable Mobility Solutions

**Propulsion and Alternative Fuels**
- Pilot Projects
- Viability Studies
- Utilization in Fleets

**Knowledge Transfer and Dissemination**
- Courses and Workshops
- Seminars and Conferences
- Educational simulators

**Studies & Applications**
- Simulation tool for road and railroad
- Monitorization Laboratory

**Investigation & Development**
- Pedestrian Simulation
- Sustainability of the mobility solutions
- Simulation: hybrid, CNG, hydrogen and biofuels
- Papers
- Theses
- Lectures
- Patents
The Team

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January 2006:

João Bravo
Joana Portugal
Biodiesel as an Alternative Fuel
Directive 2003/30/CE

Minimum quantity of Biofuel placed in the market, as percentage for the gasoline and the fuel for diesel engines

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>2</td>
</tr>
<tr>
<td>2006</td>
<td>2.75</td>
</tr>
<tr>
<td>2007</td>
<td>3.5</td>
</tr>
<tr>
<td>2008</td>
<td>4.25</td>
</tr>
<tr>
<td>2009</td>
<td>5</td>
</tr>
<tr>
<td>2010</td>
<td>5.75</td>
</tr>
</tbody>
</table>

2005 2006 2007 2008 2009 2010
Objective of the work

- Environmental and Energetic Analysis of the biodiesel life cycle:
  - Energy consumption
  - Pollutants emissions

- Application to a case study: the Évora Municipality Fleet, SITEE – EM;

- Comparison to the actual situation used in the fleet – diesel;

- Comparison results for different types of mixtures: B5, B20 and B100.
Biodiesel

- Diesel displacement fuel made from plant oils, animal tallow or recycled cooking oils;

- Chemical process, that removes the glycerine and yield methyl or ethyl esters optimized for combustion;

\[
\text{Vegetable Oil} \quad + \quad \text{Methanol} \quad + \quad \text{Glycerine} \\
(1 \text{ ton}) \quad + \quad (0.11 \text{ ton}) \quad + \quad (0.1 \text{ ton}) \\
\rightarrow \quad \text{Mixture of Methyl Esters} \\
(1 \text{ ton Biodiesel})
\]

- Purification Process in Europe obliges the regulation: EN 14214

- Renewable, non-toxic, usable in any percentage with a diesel mixture, allows a less energetic dependence.
• Application to the Évora Municipality Fleet:

**Urban Fleet Transport**
- 13 vehicles (Euro III)
- Average Consumption - 41.4 l/100km
- Annual Distance - 490 thousand km
- Annual Average Consumption - 200 thousand litres

**“Blue Line” Fleet**
- 4 mini-buses (Euro II)
- Average Consumption - 18 l/100km
- Annual Distance - 288 thousand km
- Annual Average Consumption - 52 thousand litres

Together their consumption is 253 thousand l/year of diesel
The Case Study - Évora

- 4 mini-buses connecting the peripheral parks of the city to the historical centre
- Circuit crossed in the pavement with a blue line
- Outside the city walls, bus stops
- Inside the Walls: just wave to stop the mini-bus
- Without a pre-defined schedule
The “Blue Line”
The Case Study - Évora

- Biodiesel production from recycled cooking oils;
- Reutilization of a residue produced in large quantities and that in Portugal doesn’t has an appropriate final use;
- HORECA (Hotel, Restaurants and Coffees) Group considered for the Historical Centre of Évora

Collect System adopted:
- HORECA Group: 191 establishments;
- Daily Production of 2 L: every 15 days, collected in a door to door system;
- Vehicle: Mercedes Sprinter 308 CDI (consumption 15 l/100km);
Methodology Adopted – WTW Analysis

Well to Tank

- Exploration
- Refinery
- Transport
- Supply

Emissions
Fuel Consumption

Tank to Wheel

Operation
Methodology Adopted – WTW Analysis

• **Production Phase: Software Gabi 4**

• Necessity to create different plans:
  - Electricity
  - Biodiesel
  - Diesel

• **Utilization Phase:**

  Fuel Consumption
  
  Diesel: COPERT III
  
  Biodiesel

  Using distances covered, consumptions of the vehicle and the Heating Value

  CO₂: EF X Fuel Consumption

  CO, NOₓ, COV, PM: COPERT and EPA Study
Main Results

Energetic Characterization – Production Phase

Used Cooking Oils vs Diesel

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>B5</th>
<th>B20</th>
<th>B100</th>
</tr>
</thead>
<tbody>
<tr>
<td>MJ/MJ Fuel</td>
<td>1,19</td>
<td>1,19</td>
<td>1,18</td>
<td>1,10</td>
</tr>
</tbody>
</table>

Energy

- 0,1%
- 1%
- 8%
Main Results

Fuel Consumption (l/year) - Utilization Phase

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Consumption (l/100km)</th>
<th>Blue Line</th>
<th>Urban Fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>18</td>
<td>41,4</td>
<td></td>
</tr>
<tr>
<td>B5</td>
<td>18,1</td>
<td>41,6</td>
<td></td>
</tr>
<tr>
<td>B20</td>
<td>18,3</td>
<td>42,0</td>
<td></td>
</tr>
<tr>
<td>B100</td>
<td>19,5</td>
<td>44,9</td>
<td></td>
</tr>
</tbody>
</table>

**Gasóleo**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Consumption (l/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasóleo</td>
<td>253.000</td>
</tr>
<tr>
<td>B5</td>
<td>254.000</td>
</tr>
<tr>
<td>B20</td>
<td>257.000</td>
</tr>
<tr>
<td>B100</td>
<td>275.000</td>
</tr>
</tbody>
</table>
Main Results

Environmental Performance - Life Cycle Analysis

CO₂ Emissions (ton/year)

Emissions CO₂

Diesel | B5 | B20 | B100
-------|----|-----|-----
674    | 675| 676 | 686

+ 0,1% | + 0,3% | + 2%

CO₂ Emissions

- Emissions from fossil fuel sources
- Emissions from renewable sources
Main Conclusions of the Work

• The Energy Consumption is Lower when using biodiesel:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Saving in diesel (l/year)</th>
<th>Number of barrils</th>
</tr>
</thead>
<tbody>
<tr>
<td>B5</td>
<td>13.000</td>
<td>90</td>
</tr>
<tr>
<td>B20</td>
<td>54.000</td>
<td>380</td>
</tr>
<tr>
<td>B100</td>
<td>253.000</td>
<td>1760</td>
</tr>
</tbody>
</table>

• An increase of fuel consumption was verified in the fleet when using biodiesel (lower heating value);

• Environmental performance: an increase in the emissions of CO$_2$ and NO$_X$ was noticed, compared to a decrease in other pollutants like CO, PM and COV;