Best Available Techniques (BAT)

Technical review and assessment of emission control techniques on mobile sources
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EGTEI meeting, Brussels, 9 October 2014

Assessment of candidate techniques
A European Commission (DG Environment) project

Some key messages

- BAT is not necessarily the latest technology
  - Existing stock also of interest
  - GP covers regions of various technological progress
  - It can be a non-technical measure

- The report needs to offer options both for highly developed and less developed regions

- We are not aiming at electing a winner technique
  - Rather offer options and assess their potential
Rationale for the assessment

→ New vehicles
  → Technology for latest Euro standards by definition considered as BAT for new vehicles

→ Existing stock is a good candidate for measures
  → Retrofitting (in-use vehicles), fuel switching, etc.
  → Most of the emphasis is given to these vehicles

→ Future vehicles
  → Potential for early introduction of promising techniques to achieve better performance than current applicable Euro standards

Presentation in the report

→ Road vehicles
  → Gasoline road vehicles
    • Mopeds and motorcycles
    • LDVs (cars, vans, light commercial vehicles)
  → Diesel road vehicles
    • LDVs (cars, vans, light commercial vehicles)
    • HDVs (trucks, buses)

→ Non-road mobile machinery (NRMM)
  • Gasoline engines (including boats)
  • Diesel engines (including rail)

→ Diesel vessels
→ Aircrafts (simplified approach)
Collation of measures from different fields

<table>
<thead>
<tr>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main pollutants per mobile source are targeted</strong></td>
<td>NOx reduction in heavy duty diesel road vehicles</td>
</tr>
</tbody>
</table>

Techniques from different categories

<table>
<thead>
<tr>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine measures</td>
<td>Exhaust Gas Recirculation (EGR)</td>
</tr>
<tr>
<td>Aftertreatment</td>
<td>Selective Catalytic Reduction (SCR)</td>
</tr>
<tr>
<td>Fuels</td>
<td>Natural gas (CNG)</td>
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<tr>
<td></td>
<td>……</td>
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<td></td>
<td>……</td>
</tr>
<tr>
<td>Powertrain</td>
<td>Hybridization</td>
</tr>
<tr>
<td>Non-technical</td>
<td>Enhanced Inspection and Maintenance (I/M)</td>
</tr>
</tbody>
</table>

Main criteria for the assessment

- Collation of information for the assessment of each measure
- The techniques are summarized with respect to the main assessment criteria
  1. **Emission reduction potential** (for the main pollutant addressed) compared to the reference technology
  2. *Indicative* `additional cost` per vehicle relative to reference technology
  3. **Environmental side-effects** (positive/negative) and synergies
  4. **Limitations** and implementation issues
**Example: Summary of BAT candidates for HDV NOx**

Placement of candidates to evaluation grid

1st step: The two key criteria (environmental benefit and cost) are used to place various techniques on the evaluation grid.

Techniques that fall in the green cells appear **more probable** to be recognized as BAT than those in the red cells, i.e.:

- **Very probable BAT**: high environmental benefit at low cost
- **Improbable BAT**: low benefit at high cost
Example: HDV NO\textsubscript{x} reduction
(limited to some techniques for clarity)

Latest and recent Euro standards placed on environmental benefit axis for reference

Some remarks on the placement of techniques

- **Relative placement:**
  - Positioning based on order of magnitude estimates, not absolute values (**not be scaled**)
  - The box is important not placement within the box

- **Additional cost is assessed for a period of 10 years and encompasses to the degree possible:**
  - Purchase and installation costs
  - Operation costs
  - Maintenance costs
How two additional criteria are used

- Starting with techniques classified as ‘very probable BAT’ and going from dark green cells to light green
  - Grey, light red, dark red are discussed for completeness
- Bottlenecks and limitations on the remaining criteria (environmental side effects, limitations in applicability, implementation issues) are more qualitatively reviewed

Example:

<table>
<thead>
<tr>
<th>SCR</th>
<th>*...</th>
</tr>
</thead>
</table>
|     | • Urea additive has to be made widely available, since periodic refilling is required; risk for ‘ammonia slip’.
|     | • SCR is a BAT having some limitations e.g. urea infrastructural needs, lower efficiency in low-load city driving. |

Example of assessment 1

NOₓ reduction in heavy duty diesel road vehicles
**Placement on grid**

**Assessment – 1/3**

Starting from dark green options

- **SCR** is a cost-effective technology to reduce NOx from diesel HDVs. It is ideal for OEM applications, but retrofit systems are also available and effective.
- Urea additive has to be made widely available, since periodic refilling is required; risk for 'ammonia slip'.
- **SCR** is a BAT with main issues for consideration the urea infrastructural needs and the low efficiency in low-load city driving that may be observed.
### Assessment - 2/3

**Going to light green**

| Hybridization | • Can reduce NO\textsubscript{x} and practically offer a decrease in most pollutants, with additional high fuel consumption benefits.  
|              | • Can be considered as BAT (especially for buses), with main limitation the high initial capital cost (although fuel efficiency improvements may lead to cost benefits in the long run).  
|              | • Hybrid trucks not at mass production yet. |

| CNG         | • Conversion to NG can lead to some NO\textsubscript{x} reduction, but the technical complications, fuel availability, and high initial costs are limiting factors; NG for trucks is still at experimental scale. CH\textsubscript{4} emissions may increase in some applications.  
|             | • Hence, NG is considered as BAT especially for OEM applications in captive fleets (e.g. buses). |

### Assessment - 3/3

**Assessment**

| DME         | • It is a NG liquid derivative, offering similar emission reduction profile. Easier handling for refueling and storage. Experience in DME-fuelled vehicles is limited. More appropriate for dedicated fleets (e.g. buses) or for use in fuel cells.  
|             | • It can be considered for diesel replacement in future, but the issues of production and distribution must be addressed first. |

| EGR         | • Reduces NO\textsubscript{x} but less effectively than SCR. Slightly reduces engine power.  
|             | • Requires low sulfur fuel and major engine integration effort when retrofitted.  
|             | • Limited potential due to technical difficulties integrating this on existing engines. |
Example of assessment 2

PM reduction in diesel NRMM (non-road mobile machinery)

Placement on grid

BAT candidates for PM reduction in diesel non-road mobile machinery (NRMM) and rail

- Stage V
  - Very probable BAT
  - Probable BAT
  - Neutral
- Stage IV
  - Hybridization
  - Emulsified diesel
  - Renewable diesel
  - CCV
- Stage III
  - Probable BAT
  - Rather improbable BAT
- Stage II
  - Improbable BAT
- Stage I
  - Improbable BAT

Cost
### Assessment - 1/3

Starting from dark green options

<table>
<thead>
<tr>
<th><strong>DPF</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• DPF is a cost-effective option to reduce PM from diesel NRMM with many successful examples of implementation. It is ideal for OEM, but retrofit systems are also available and effective.</td>
</tr>
<tr>
<td>• Attention to possible increase of NO₂ from catalyzed DPFs; there may also be a fuel economy penalty ~1-2%.</td>
</tr>
<tr>
<td>• DPF is a BAT when low sulfur fuel is available. Regeneration at high temperatures and periodic maintenance with cleaning system are required.</td>
</tr>
</tbody>
</table>

### Assessment - 2/3

Dark green options

<table>
<thead>
<tr>
<th><strong>Natural Gas</strong></th>
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<tbody>
<tr>
<td>• Conversion to NG can lead to high PM reduction, but technical complications, fuel availability, and high initial costs are limiting factors; gas tanks may prohibitively increase vehicle weight. CH₄ emissions may increase in some applications.</td>
</tr>
<tr>
<td>• Hence, NG is considered as BAT especially for OEM applications. The experience is limited as retrofit.</td>
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</tbody>
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<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>• DME is an NG liquid derivative, offering similar emission reduction profile. Easier handling for refueling and storage. Experience in DME-fuelled vehicles is limited. More appropriate for dedicated fleets.</td>
</tr>
<tr>
<td>• It can be considered as a diesel replacement in the future, but issues of production and distribution must be addressed first.</td>
</tr>
</tbody>
</table>
### Assessment - 3/3

#### Light green options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Hybridization** | • Can reduce PM and practically offer a decrease in most pollutants, with additional high fuel consumption benefits.  
• Can be considered as BAT with main limitations the high initial capital cost (although there may be fuel cost benefits in the long run) and the fact that it is not at mass production yet. Potential to be further established in the future. |
| **DOC** | • Reduces PM less than other options, but it has low installation cost and no specific limitations or maintenance requirements. Possible increase of NO2 fraction of total NOx.  
• Can be considered as BAT (e.g. retrofits in large-scale applications) being more tolerant to fuel sulfur than DPF and when other technical factors exclude the applicability of DPFs. |

### Example of assessment 3

**NOx reduction in diesel vessels**
**Assessment - 1/2**

Starting from dark green options

- **SCR**
  - SCR is a cost-effective technology to reduce NOx from diesel vessels. It is ideal for OEM applications, but retrofit systems are also available and effective.
  - Urea additive has to be made widely available, since periodic refilling is required; risk for ‘ammonia slip’.
  - SCR is a BAT with main issues for consideration the urea infrastructural needs and the lower efficiency that may be observed in low-loads <25% and during slow steaming.

**Placement on grid**

- BAT candidates for NOx reduction in diesel vessels

- SCR
- UNG
- EGR

- Cost
- Environmental Benefit

- **Low cost**
  - Very probable BAT
  - Rather improbable BAT

- **High cost**
  - Improbable BAT
  - Neutral
**Assessment - 2/2**

### Going to light green

**LNG**
- Conversion of a ship to run on natural gas (LNG) can lead to NO\textsubscript{x} reduction, but technical complications, fuel availability, and high initial capital costs are limiting factors. Moreover, gas tanks may limit vessel storage space and increase weight. CH\textsubscript{4} emissions are usually increased.
- Hence, LNG is a BAT especially for OEM applications, but as a retrofit, substantial modifications are required and the experience is limited.

**EGR**
- EGR in diesel vessels may achieve NO\textsubscript{x} reduction efficiency which can be higher than in road vehicles. Slightly reduces engine power.
- EGR for ships is not a mature technology yet and there are many drawbacks and limited use as a retrofit.

### Evaluation summary - example

<table>
<thead>
<tr>
<th>Technology</th>
<th>Compression ignition engines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LDVs</td>
</tr>
<tr>
<td>Exhaust Gas Recirculation (EGR)</td>
<td>1</td>
</tr>
<tr>
<td>Lean NO\textsubscript{x} Trap (LNT)</td>
<td>2</td>
</tr>
<tr>
<td>Selective Catalytic Reduction (SCR)</td>
<td>3</td>
</tr>
<tr>
<td>Diesel Oxidation Catalyst (DOC)</td>
<td>2</td>
</tr>
<tr>
<td>Diesel Particle Filter (DPF)</td>
<td>3</td>
</tr>
<tr>
<td>Compressed Natural Gas (CNG)</td>
<td>3</td>
</tr>
<tr>
<td>Liquefied Natural Gas (LNG)</td>
<td>2</td>
</tr>
<tr>
<td>Electrification</td>
<td>2</td>
</tr>
<tr>
<td>Hybridization</td>
<td>1</td>
</tr>
</tbody>
</table>

*An overview of techniques for retrofit, new, future vehicles.*
Explanation of score values

-3: Least cost-effective technique with low environmental benefit or not applicable (due to technical, economical, or other limitations).

0: Technique with neutral impact.

3: Most cost-effective technique with high environmental benefit. Technical, economical, or other limitations may exist, but interventions to pass the threshold for implementation already exist or should be further supported in the future.