Best Available Techniques (BAT)

Technical review and assessment of emission control techniques on mobile sources

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Assessment of candidate techniques

A European Commission (DG Environment) project
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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

Not addressed in Sept. version

- 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

Description		Example
Main pollutants per mobile source are targeted		NO_x reduction in heavy duty diesel road vehicles
Techniques from different categories	**Engine measures**	Exhaust Gas Recirculation (EGR)
	Aftertreatment	Selective Catalytic Reduction (SCR)
	Fuels	Natural gas (CNG)
		……
		……
	Powertrain	Hybridization
	Non-technical	Enhanced Inspection and Maintenance (I/M)

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 NO_x

	Technique	"Expected effect"	Cost per vehicle (Euro)	Environmental side effects and synergies (positive	/ negative)	Limitations in applicability	Implementation and other issues
Engine measures	A. Exhaust Gas Recirculation (EGR)	25-45%	1,600 (indicative manufacturer cost)	n.a.	• Slightly reduces engine power • PM recirculation if not combined with a DPF	• Ultra Low Sulfur Diesel (ULSD) required <50ppm • Electronic control strategy required to ensure operation	• Major engine integration when retrofitted • Exhaust cooling may result in engine wear due to excess water vapour
Aftertreatment	B. Selective Catalytic Reduction (SCR)	70-95%	7,500 installation (one-off) +500 urea +200 maintenance -800 possible fuel savings (OEM) per year (*)	• Reduction of VOC (50-90%), CO (50-90%), PM (20-40%) • 3-5% possible fuel consumption benefits (OEM applications) • Reduction of the characteristic odor produced by a diesel engine and smoke	Risk for "ammonia slip"	• Urea additive must be available • Certain temperature criteria for NO_x reduction to occur (data logging) • Lower efficiency in low-load city driving (low exhaust gas temperatures)	• Requires infrastructure for urea additive • Periodic refilling with urea required (on-board dosing unit) • SCR units are large, heavy, complex and bulky systems
Alternative powertrain and fuels	C. Conversion to natural gas (CNG)	20-50%	12k-15k (one-off for conversion) minus 500-1,000 fuel cost benefits per year	• Reduction of PM and BC (85-95%), CO (70-95%), NMVOC (75-85%) • Lower CO_2 emissions due to lower carbon content	• Low volumetric energy content • Not so effective in PN as DPF • Increase of CH_4 emissions	• Availability of fuel • Gas tank limits storage space and increases vehicle weight • Driving range may decrease (better for urban applications)	• May require significant changes to fueling infrastructure and maintenance facilities • Limited experience in long term truck performance
	D. Emulsified diesel	10-20%	1,200-1,600 per year (**)	Reduction of PM (50-60%)	Decrease in power and fuel economy	Availability of fuel	Over time the water can settle out of the emulsified fuel and may cause performance problems
	E. Hybridization (off-vehicle or on-vehicle charging)	40-50%	50k-100k (one-off) minus 5k-10k energy and maintenance cost benefits per year	• High fuel consumption benefits (especially buses) • Similar decreases in practically all pollutants • Low noise and PM resuspension, especially taking off from bus stops	n.a.	• Recharging necessary for off-vehicle charging vehicles • Driving range may decrease (better for urban applications)	Trucks not at mass production yet
Non-technical	F. Enhanced Inspection and Maintenance (I/M)	15-35%	300-500 (***)	• Decrease of other pollutants through maintenance • Improvement of vehicle safety	n.a.	Police enforcement may be necessary	• Infrastructural changes (retooling of I/M stations, education of personnel) • Suitability of locations for remote sensing

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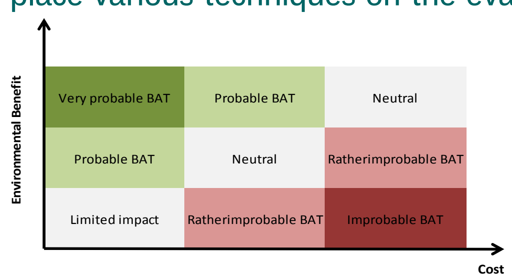
Placement of candidates to evaluation grid

- 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

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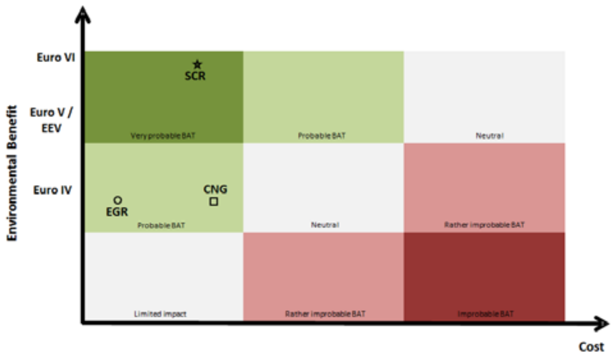
Example: HDV NO_x reduction (limited to some techniques for clarity)



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:

SCR	• … • **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.**

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Example of assessment 1

NO_x reduction in heavy duty diesel road vehicles

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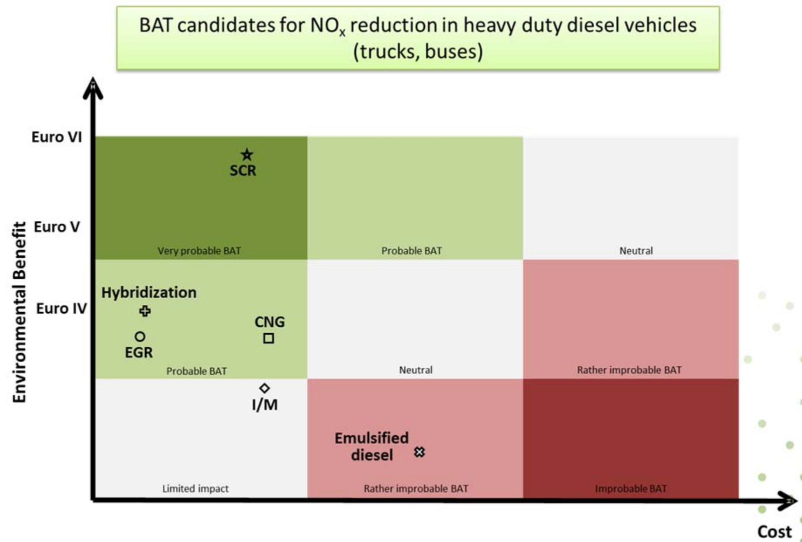
Placement on grid



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Assessment – 1 / 3

Starting from dark green options

SCR	•SCR is a cost-effective technology to reduce NO_x 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.

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Assessment – 2 / 3

Going to light green

Hybridi-zation	•Can reduce NO_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_x reduction, but the technical complications, fuel availability, and high initial costs are limiting factors; NG for trucks is still at experimental scale. CH_4 emissions may increase in some applications. •Hence, NG is considered as BAT especially for OEM applications in captive fleets (e.g. buses).

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Assessment – 3 / 3

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_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.

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Example of assessment 2

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

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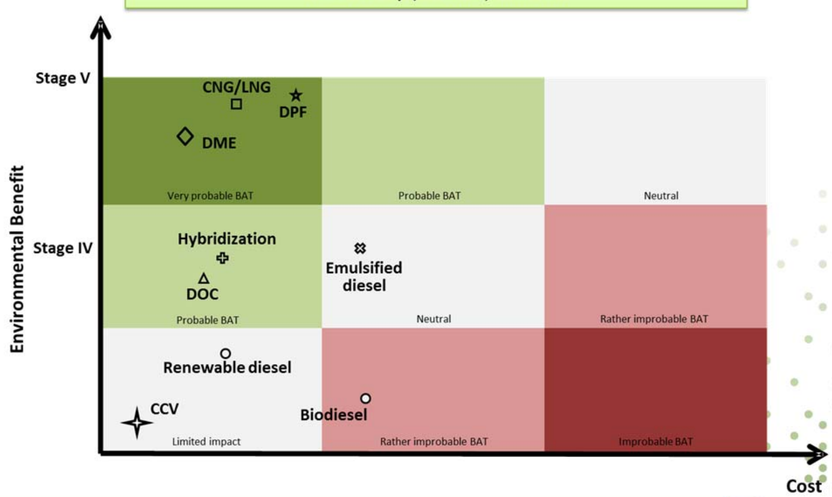
Placement on grid

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



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Assessment – 1 / 3

Starting from dark green options

DPF	•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. •Attention to possible increase of NO_2 from catalyzed DPFs; there may also be a fuel economy penalty ~1-2%. •DPF is a BAT when low sulfur fuel is available. Regeneration at high temperatures and periodic maintenance with cleaning system are required.

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Assessment – 2 / 3

Dark green options

Natural Gas	•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. CH_4 emissions may increase in some applications. •Hence, NG is considered as BAT especially for OEM applications. The experience is limited as retrofit.
DME	•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. •It can be considered as a diesel replacement in the future, but issues of production and distribution must be addressed first.

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Assessment – 3 / 3

Light green options

Hybridi-zation	•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 NO_2 fraction of total NO_x. •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.

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Example of assessment 3

NO_x reduction in diesel vessels

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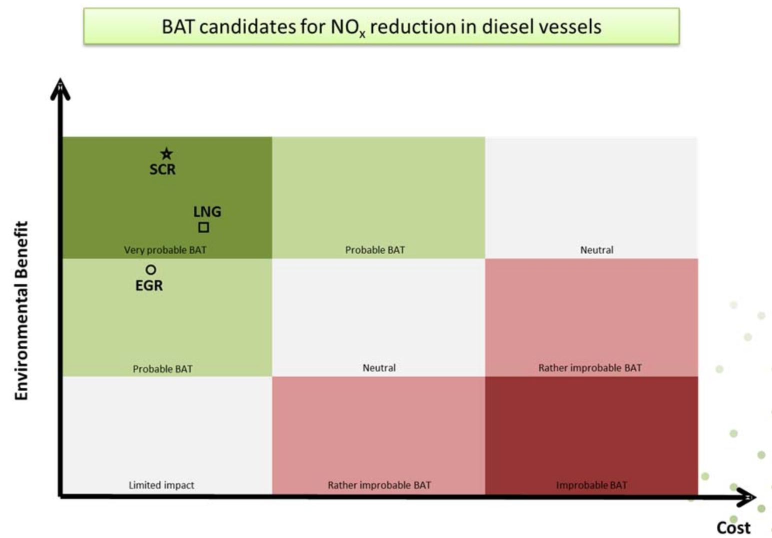
Placement on grid



Assessment – 1 / 2

Starting from dark green options

SCR	•SCR is a cost-effective technology to reduce NO_x 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.

Assessment – 2 / 2

Going to light green

LNG	•Conversion of a ship to run on natural gas (LNG) can lead to NO_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_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_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

Technology	Compression ignition engines											
	LDVs			HDVs			NRMM / Rail			Vessels		
	N	R	F	N	R	F	N	R	F	N	R	F
Exhaust Gas Recirculation (EGR)	1	-1	0	1	-1	0	1	-1	0	1	-1	0
Lean NO_x Trap (LNT)	2	2	1									
Selective Catalytic Reduction (SCR)	3	3	2	3	3	2	3	3	2	3	3	2
Diesel Oxidation Catalyst (DOC)	2	1	0	2	2	0	2	1	0			
Diesel Particle Filter (DPF)	3	3	2	3	3	2	3	3	2	1	0	0
Compressed Natural Gas (CNG)	3	1	2	3	1	2	2	1	2			
Liquefied Natural Gas (LNG)				2	1	1	2	1	1	3	1	2
Electrification	2	-3	3	1	-3	2	1	-3	3			
Hybridization	1	0	2	1	0	2	1	0	2			

- 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.

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