IEA Implementing Agreement on Advanced Motor Fuels

Reducing Particle Emissions: the Growing Demand for Alternative Fuels

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Outline

- Defining environmental performance
- Composition of particles
- Fuels for reduced particle emissions
- IEA AMF activies
- Summary

Definitions

- **A local environmental problem**

  ”A problem that threatens your health and well-being already today”

- **A global environmental problem**

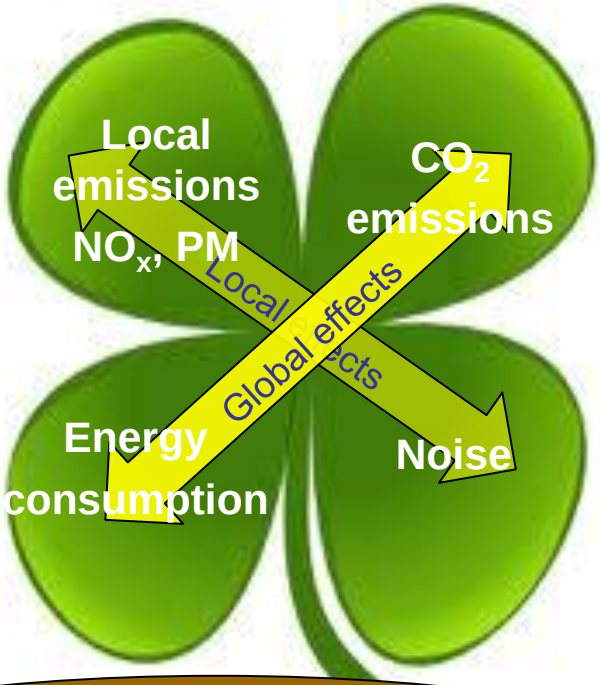
  ”A problem that threatens your existence in the future”

- **So how can alternative fuels help us?**

Photo: Markku Ikonen (Tanzania 1991)

Environmental friendliness

Multi-dimensional contemplation



A fluent intelligent transport system
Service and safety

International Agency for Research on Cancer

World Health Organization

PRESS RELEASE
N° 213

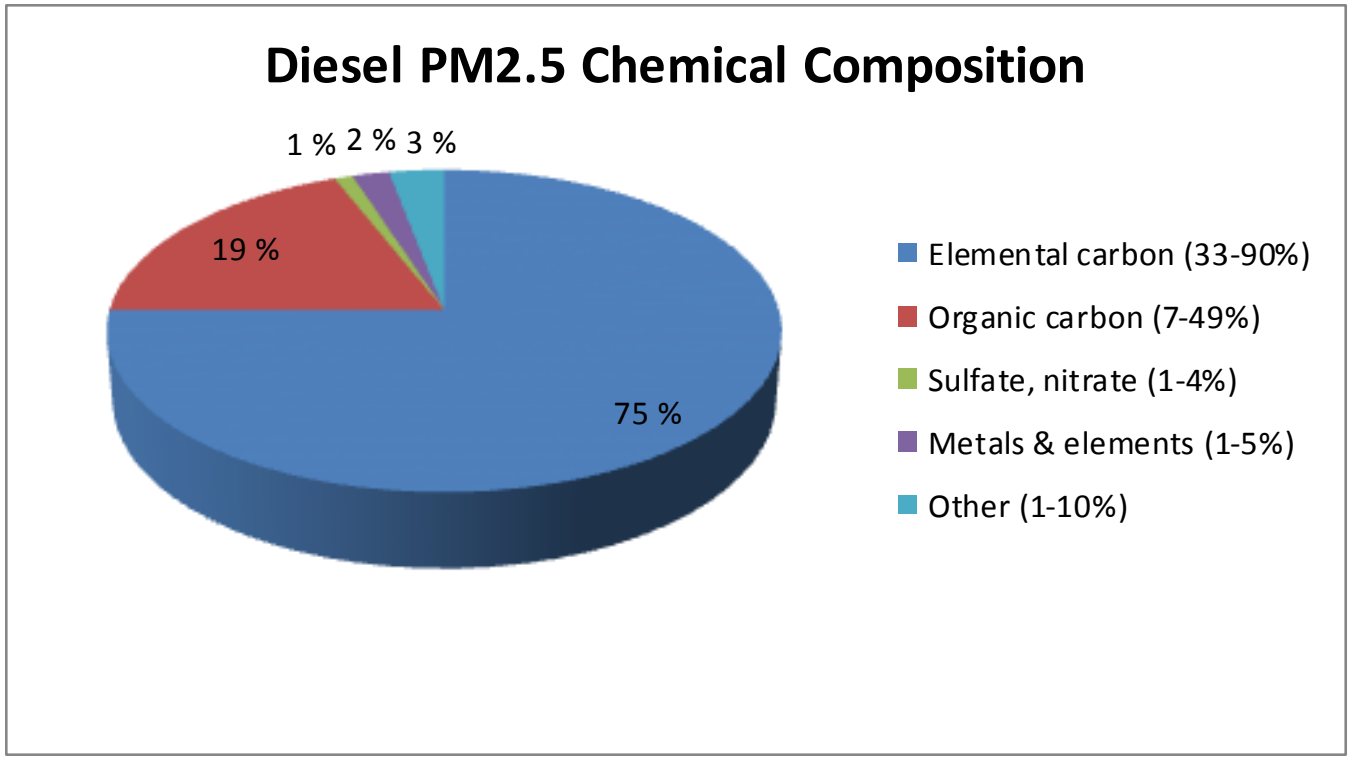
12 June 2012

IARC: DIESEL ENGINE EXHAUST CARCINOGENIC

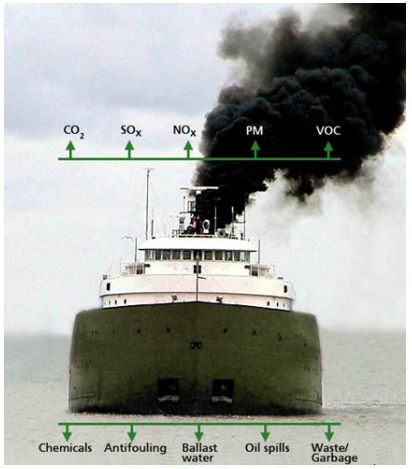
Lyon, France, June 12, 2012 -- After a week-long meeting of international experts, the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), today classified diesel engine exhaust as **carcinogenic to humans (Group 1)**, based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

http://press.iarc.fr/pr213_E.pdf

Diesel particle composition

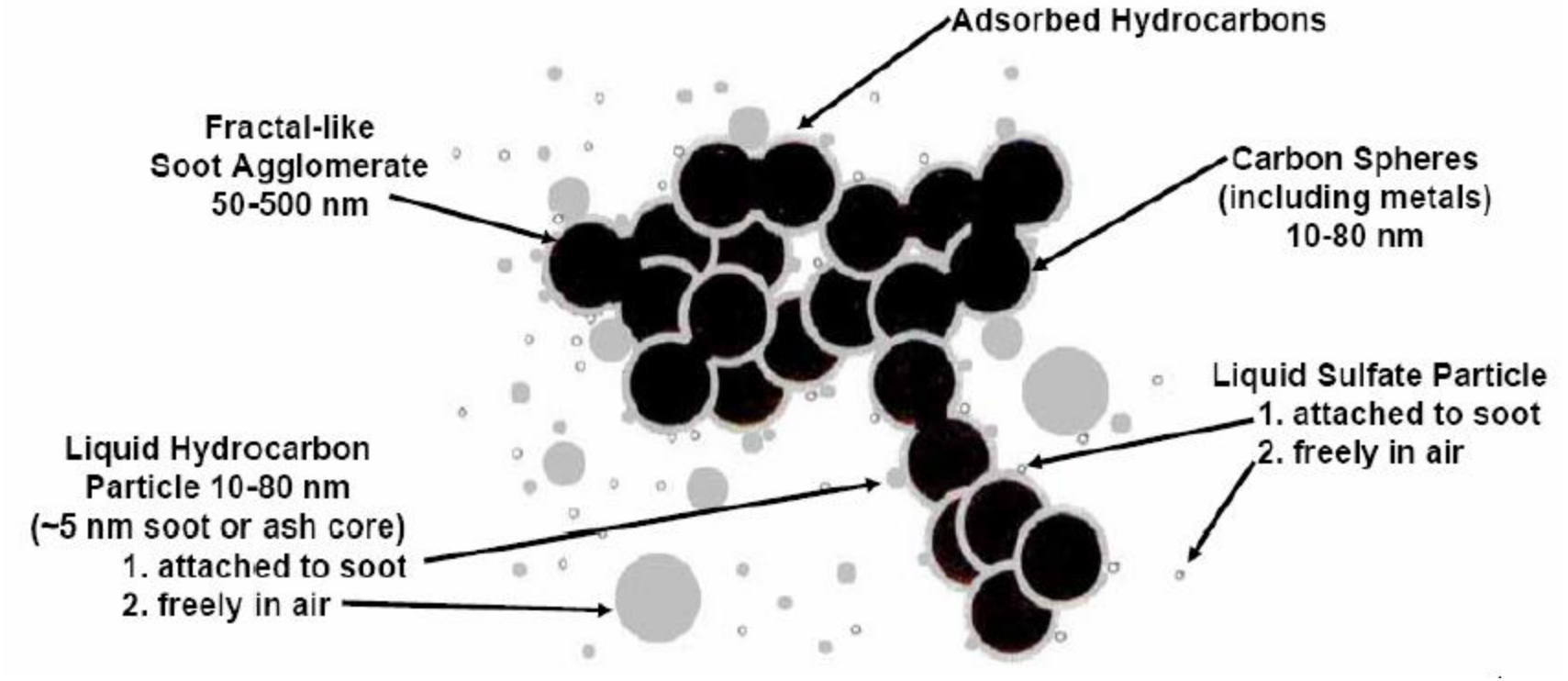


Source: US EPA 2002



Ship picture: Vareide 2012

Scematic figure of diesel particles



Note: Black carbon also increases global warming

Source: Foster 2004

Health effects of particles

- Coarse particles
  - diameter >1 µm, not very harmful
- Accumulation mode particles
  - diameter 30-50 nm....1 µm
  - mostly products of incomplete fuel combustion, soot
  - carry suspected genotoxic constituents of the emission (higher molecular weight PAH compounds)
- Nanoparticles
  - diameter <30–50 nm, mostly condensed volatiles
  - typically more than 90 % of total particle number (advanced engines)
  - penetrate into the lowest parts of the respiratory tract
  - they may dissolve into the body fluids and the blood circulation system (non-solid nature)

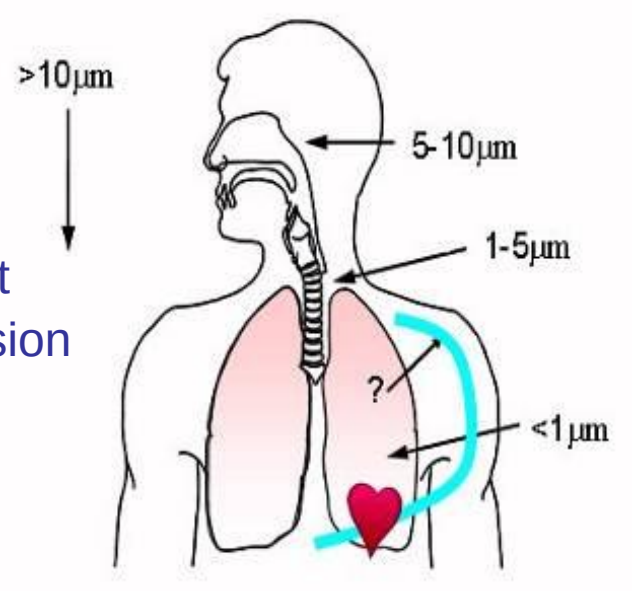


Figure: Sam Altshuler

Factors affecting particle emissions

- Engine configuration
  - Diesel vs. spark-ignition
  - Turbocharging
  - Injection system
- Fuel
  - Chemically simple fuels give low particle emissions
  - Low-sulfur fuels enable the use of exhaust after-treatment
- Exhaust after-treatment
  - Catalysts, particle catalysts (p-DPF), wall-flow filters (DPF)
  - Filter clogging and NO2 formation can cause trouble
- Running conditions
  - High load promotes particle formation

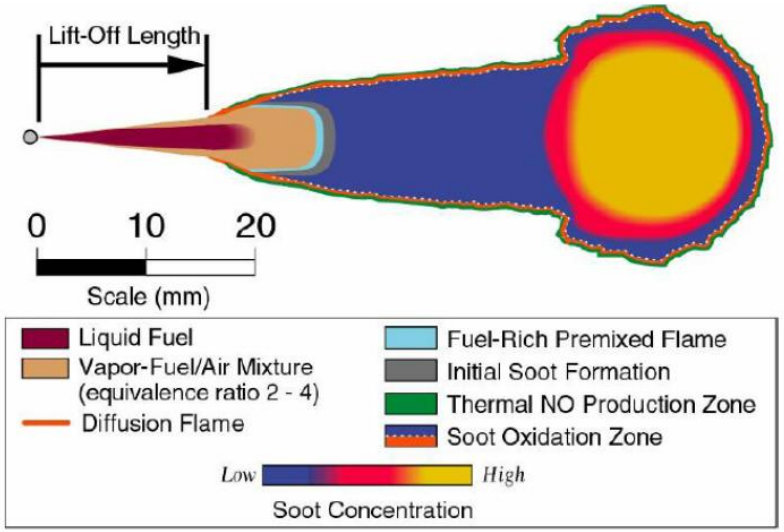
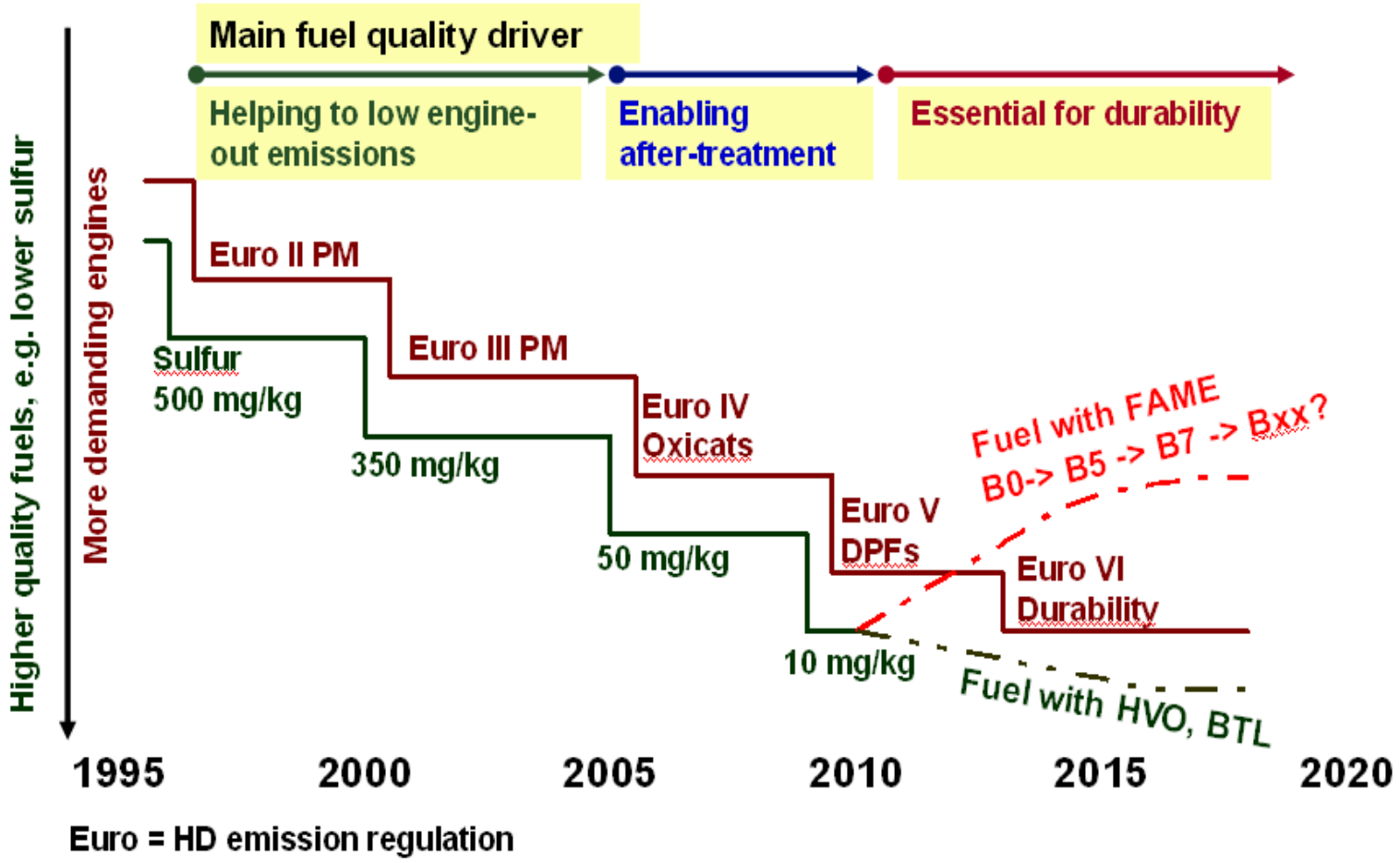


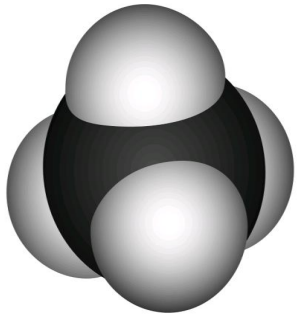
Figure: Musculus et al. 2005

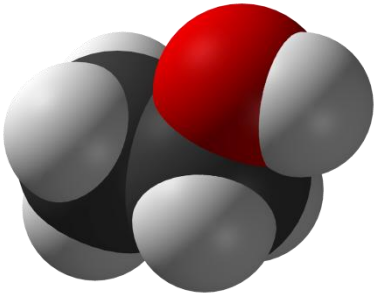
Evolution of diesel emissions and fuel quality



Source: Seppo Mikkonen/Neste Oil 2011

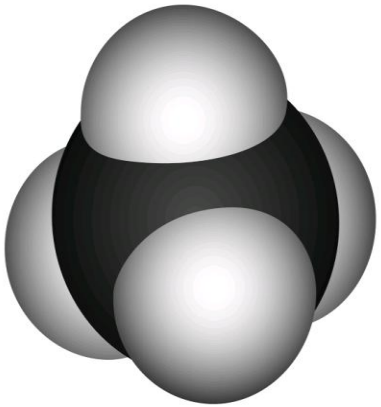
Fuels for reduced particle emissions





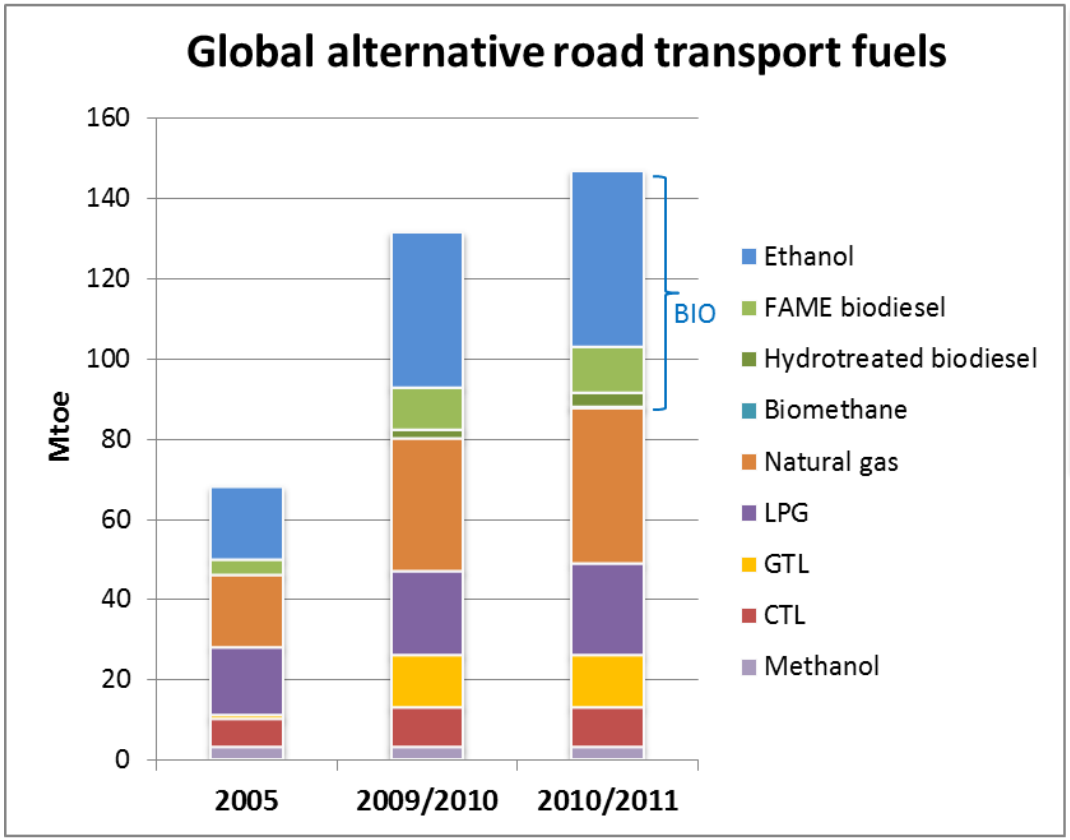
- Gasoline instead of diesel
  - In light-duty vehicles
- Paraffinic (synthetic) diesel instead of regular diesel
- Gaseous fuels
  - Natural gas, LPG
- Oxygenated fuels
  - Alcohols, ethers, esters (conventional biodiesel)
- In general:
  - Chemically simple low-sulfur fuels with low boiling temperature
- The best alternative fuels provide fuel substitution as well as reduced emissions

Methane (natural gas, biogas)



- Methane (CH_4) is the main constituent of natural gas and biogas
- Methane is the simplest alkane with no carbon-to-carbon bonds
- Methane can easily replace gasoline, but methane is not suitable for conventional compression ignition (diesel) engines
- Methane is rather hard to ignite, but when ignited, it burns cleanly
- Methane is not toxic
- Methane is one of the best alternatives for urban buses
- Unburned methane must be controlled (strong GHG)

Fuel volumes in road transport (world, current)



Energy demand of transport sector is appr. 2300 Mtoe. Major part of that, appr. 73% (~ 1700 Mtoe), is consumed in road transport sector.

Alternative fuels are estimated to represent max. 8.8% share of road transport fuels in 2010. Share of biofuels is estimated to be 3.5%, respectively.

Sources: Ethanol 2010 (REN21, 2011); FAME and hydrotreated biodiesel 2010/2011 (EurObserv'ER, 2011; Press releases); CNG, biomethane 2010/2011 calculated from vehicle population (NGVA Europe and GVR, 2011); GTL and CTL capacities (IEA ETSAP, 2010); Methanol 2010 (Methanol Institute); World transport fuels 2009 (IEA WEO, 2011).

Figure by IEA-AMF (A-S 2012)

Table compiled by Päivi Aakko-Saksa/VTT for IEA Advanced Motor Fuels 2012

What is IEA-AMF?

- One of IEA's eight transport related Implementing Agreements
- Long-standing agreement
  - 1984-1989 - Alcohols as Motor Fuels
  - 1990-1998 - Alternative Motor Fuels
  - 1999- today - Advanced Motor Fuels
- The Advanced Motor Fuels Program (AMF) continues to be a very active and successful program
  - the number of participating countries has grown from a beginning of four countries in 1984 to sixteen countries in 2012
    - Korea joined in October 2012
  - 44 Annexes (projects) have been initiated by the Program over the years

What is IEA-AMF?

- Within the Executive Committee of AMF, advanced motor fuels have been defined as fuels fulfilling one or more of the following criteria:
  - low toxic emissions
  - improved life cycle efficiency
  - reduced greenhouse gas emissions/utilization of renewable energy sources
  - enabling fuels for new propulsion systems
  - fuels contributing to sustainability in transportation
  - fuels contributing to security of supply

- AMF acts as an international **neutral** clearing-house for information related to transportation fuels

- AMF gathers, evaluates and disseminates information, but in addition, it generates first-line data of its own

IEA Implementing Agreement on Advanced Motor Fuels

Home

About AMF
- Activities
- Mission
- Participants

Technical Annexes

Downloadables
- Annual reports
- Project Reports
- Newsletters

Events and links
- Events
- Links

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Welcome to IEA Advanced Motor Fuels site

Advanced Motor Fuels (AMF) is one of the International Energy Agency's (IEA) transportation related Implementing Agreements. Information on IEA's structure for energy technology related R&D and IEA's Technology Agreements can be found at www.iea.org.

Transportation in itself is a function with significant impacts on energy, emissions and even on economy. The share of energy used in transportation is high, ranging typically from some 20 to 30 % of the total energy consumption. The share of harmful emissions from the transport sector is in general even higher than its share of energy usage.

The transport sector is facing many challenges. Today this sector is practically totally dependent on crude oil derived fuels. The number of vehicles around the world is increasing rapidly, and so are the environmental impacts and the use of energy in transport. Whereas many other sectors of society have been able to stabilise or cut CO_2 emissions, transport related CO_2 emissions tend to be increasing both in relative and absolute terms.

At the same time new possibilities are opening up. The array of options is widening, not closing in. This is true for both fuel and vehicle technology options. We are closer than ever to a wide-scale use of alternative fuels. Today we have biofuels and natural gas on the agenda, for tomorrow there might be synfuels and even hydrogen. We already have hybrid and natural gas vehicles in the market, as well as the first experimental series of fuel cell vehicles. At the same time, the internal combustion engine is improving, with features like direct injection, flexible engine controls and new combustion systems.

AMF provides an international platform for co-operation to promote cleaner and more energy efficient fuels and vehicle technologies. AMF welcomes interested parties to make contact and to become members of the AMF family.

News

Life Cycle Analysis report...

IEA Bus report...

Annual Report 2011...

GV Global 2012 -13th NGV Global Conference and Exhibition.

Next IEA/AMF ExCo Meeting...

More news...

Broschure

AMF Outreach
AMF Flyer

www.iea-amf.vtt.fi

Examples of AMF activities

- 22: Particulate Emissions at Moderate and Cold Temperatures Using Different Fuels (2000–2003)
- 29: Evaluation of Duty Cycles for Heavy-Duty Urban Vehicles (2004–2007)
- 37: Fuel and Technology Alternatives for Buses - Overall Energy Efficiency and Emission Performance (2008-2012)

Annex 22: Particulate Emissions at Moderate and Cold Temperatures Using Different Fuels

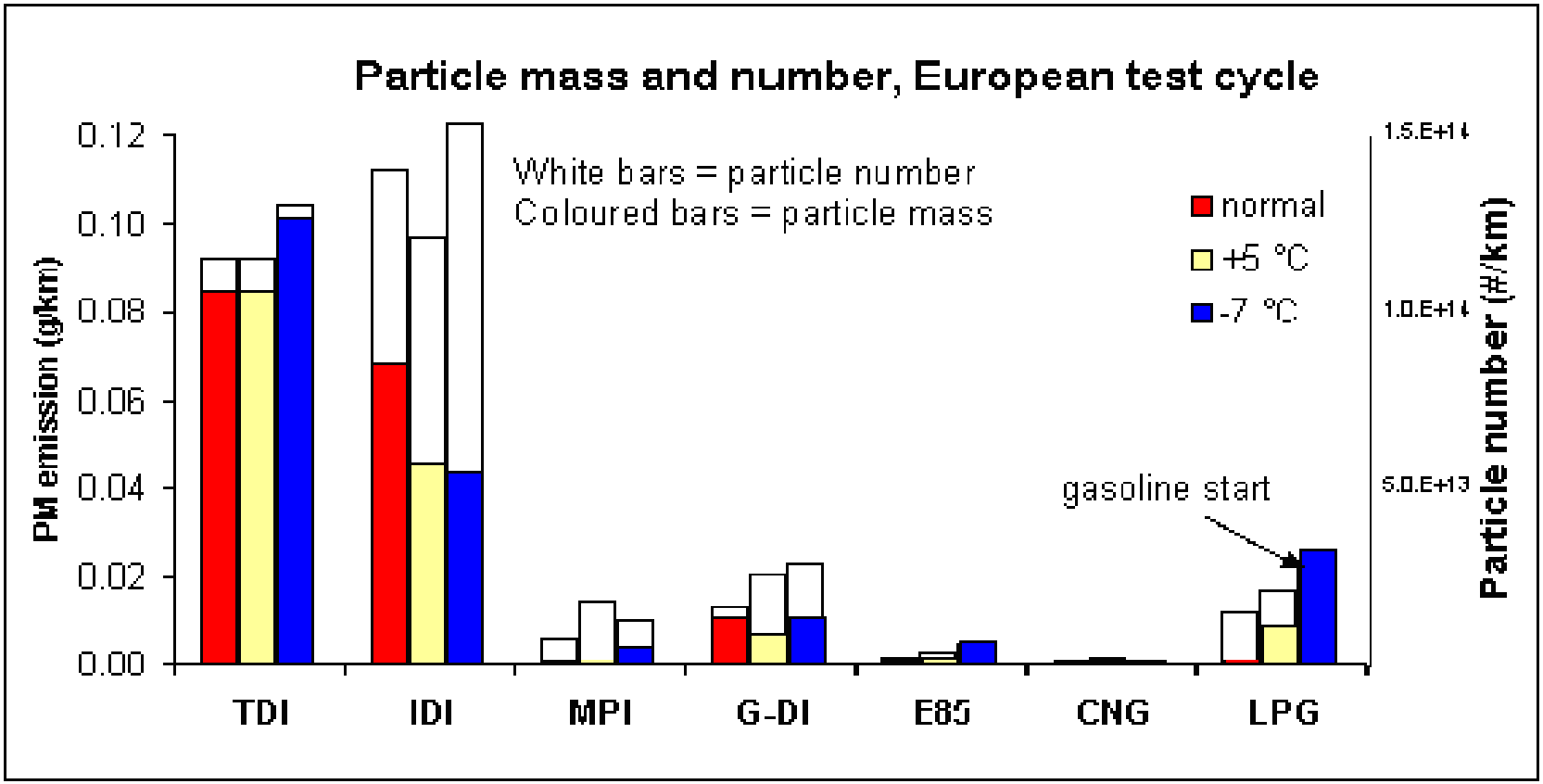
- The **objective** of the task was to produce new emission data for passenger cars on particle emissions in “off-cycle” conditions with a variety of fuels.

- The fuels/ technologies covered were:
  - gasoline and diesel
  - E85
  - CNG & LPG

- The vehicle matrix included 7 different vehicles:
  - 2 gasoline vehicles (port injection and direct injection)
  - 2 diesel vehicles (pre-chamber and direct injection)
  - 1 FFV vehicle (E85, port injection)
  - 1 CNG vehicle (dedicated mono-fuel, port injection)
  - 1 LPG vehicle (bi-fuel, port injection)

- Model year varied from 1996 to 2002

Annex 22: Particulate Emissions at Moderate and Cold Temperatures Using Different Fuels



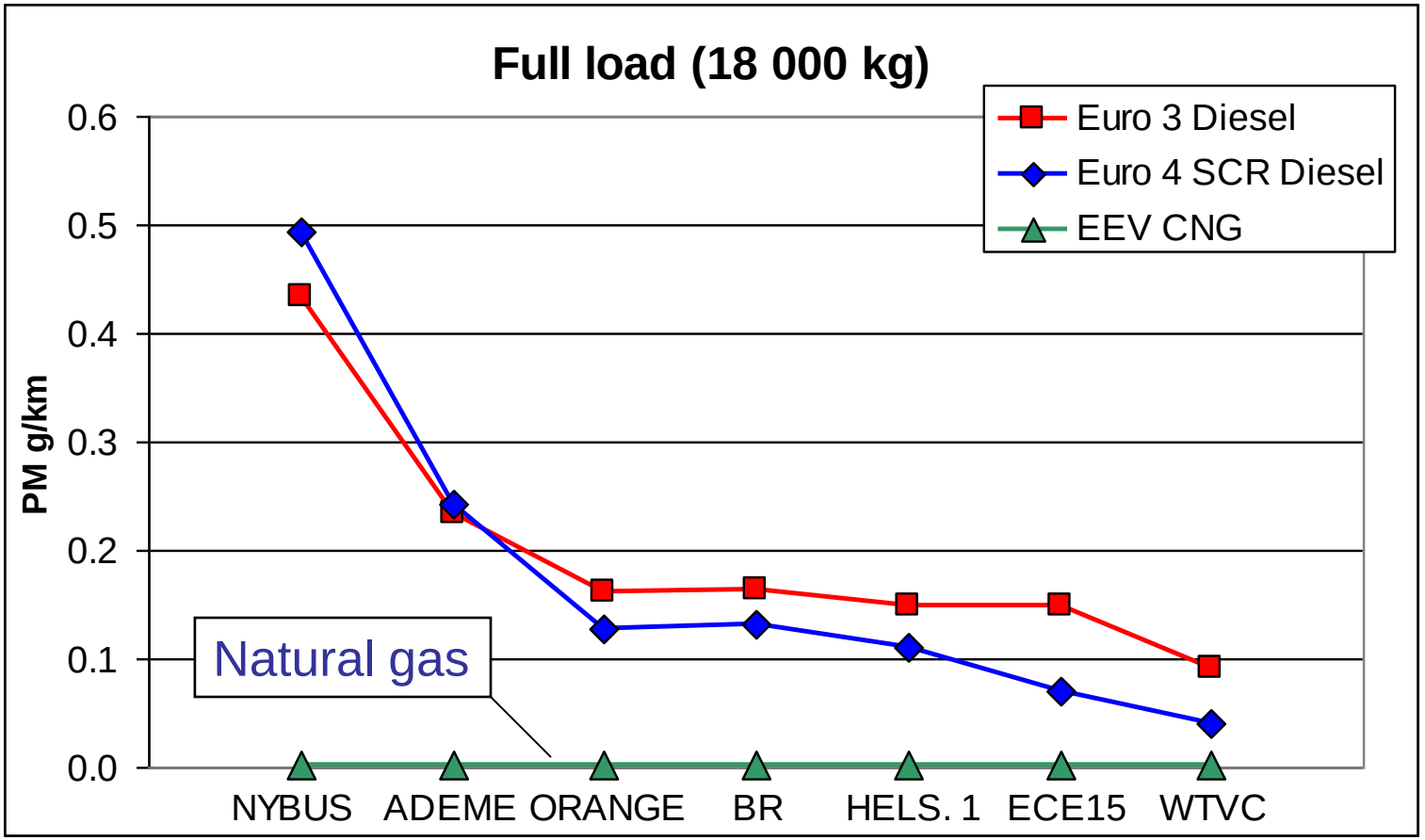
Annex 29: Evaluation of Duty Cycles for Heavy-Duty Urban Vehicles

- The main **objective** of the project was to demonstrate how the driving cycle affects the emission performance of conventional and advanced urban buses.

- In a collaborative effort of three vehicle laboratories (VTT, Environment Canada, West Virginia University) , a number of driving cycles were run with several vehicles aiming at the following goals:
  - to generate understanding of the characteristics of different duty cycles
  - to study the interaction between vehicle, exhaust after-treatment and fuel technologies and test procedures
  - to pin-point the need for international harmonization in emission testing

VTT Environment Canada West Virginia University Research Center for Alternative Fuels, Engines & Emissions iea Energy Technology Network

Annex 29: Evaluation of Duty Cycles for Heavy-Duty Urban Vehicles



Annex 37: Fuel and Technology Alternatives for Buses

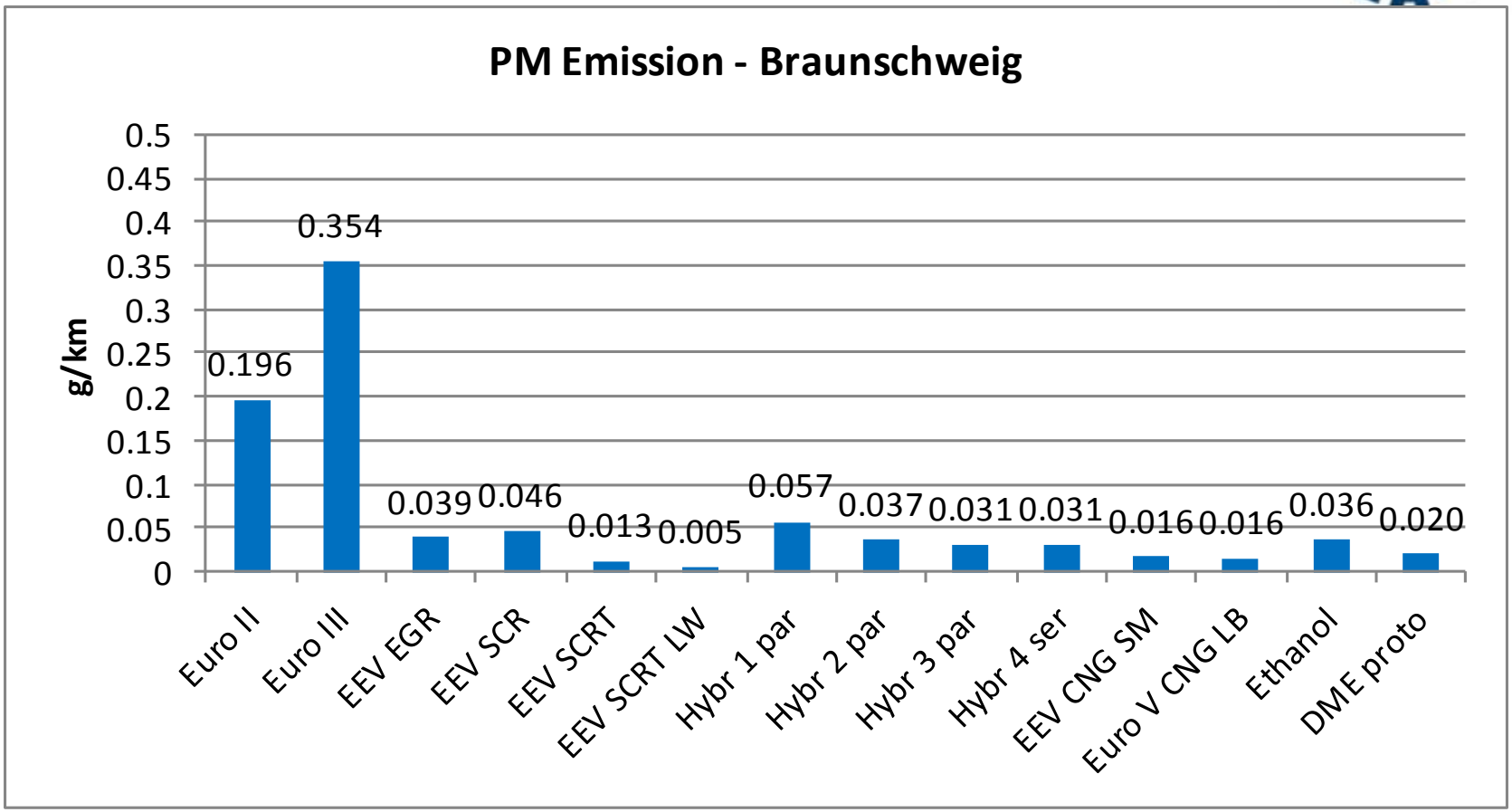
Objectives:

- To produce data on the overall energy efficiency, emissions and costs, both direct and indirect costs, of various technology options for buses
- Provide solid IEA sanctioned data for policy- and decision-makers
- Bring together the expertise of various IEA Implementing Agreements:
  - Bioenergy: fuel production
  - AFC & Hydrogen: automotive fuel cells
  - AMF: fuel end-use
  - AMT: light-weight materials
  - Combustion: new combustion systems
  - HEV: hybrids & electric vehicles

Annex 37: Fuel and Technology Alternatives for Buses

Transient chassis dynamometer testing

Annex 37: Fuel and Technology Alternatives for Buses



Annex 37: Fuel and Technology Alternatives for Buses

- Old vs. new diesel vehicles
  - 10:1 and even more for regulated emissions
  - 100:1 for particle numbers
  - close to neutral for fuel efficiency

- Hybridization and light-weighting
  - 20 - 30 % reduction in fuel consumption
  - not automatically beneficial for regulated emissions
  - energy consumption ratio between the least fuel efficient vehicle with conventional power train and the most efficient hybrid 2:1

- Effect of driving cycle
  - 5:1 for fuel consumption and regulated emissions

Annex 37: Fuel and Technology Alternatives for Buses

- Fuel effects on tailpipe emissions (when replacing regular diesel)
  - 2.5:1 at maximum for regulated emissions (particles)
  - 4:1 for unregulated emissions

- Alternative fuels (in dedicated vehicles)
  - low PM emissions but not automatically low NO_x emissions
  - fuel efficiency depends on combustion system (compression or spark-ignition)
  - diesel vs. spark-ignited CNG roughly equivalent for tailpipe CO_2

Final report now available

Some 400 pages including a 20-page Executive Summary

http://www.vtt.fi/inf/pdf/technology/2012/T46.pdf
http://www.iea-amf.vtt.fi/8annexreports.html

SAE International™

Summary

- Strive for best available technology (BAT), remove high emitters!
- Diesel exhaust has been declared carcinogenic
  - Particles are conceived the most harmful exhaust constituents
- Advanced vehicles as well as alternative fuels can bring down particle emissions
- Chemically simple fuels such as methane substantially lower exhaust toxicity compared to diesel
- Fuel effects on emissions are accentuated in less sophisticated engines
- IEA Advanced Motor Fuels acts as an international neutral clearing-house for information related to transportation fuels