Reduction and testing of GHG emissions from Heavy Duty Vehicles – Lot 1: Strategy

Nikolas Hill, AEA
Hannah Baker, Ricardo
Ian Skinner, TEPR

AEA

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RICARDO

nikolas.hill@aeat.co.uk
+44 (0)870 190 6490

Outline

1) Background and Objectives

2) Project Outline
   - Task 1: Vehicle Market and Fleet
   - Task 2: Fuel Use and CO_2 emissions
   - Task 3: Technology
   - Task 4: Policy Assessment

3) Summary of Key Results – Focus on Technology

4) Summary and Final Conclusions

Background

The European Commission adopted a strategy for addressing the CO_2 emissions from light-duty vehicles (COM(2007)19) which is based on an integrated approach.

The European Council and European Parliament agreed on 18 December 2008 on this new Regulation which will limit CO_2 emissions from EU registered passenger cars to 130 gCO_2 /km by 2015 (phased in from 2012), and further to 95 gCO_2 /km by 2020.

According to the strategy, the integrated approach also includes legislation to limit the emission levels of Light Commercial Vehicles.

This project was an initial step in the processes building a new GHG reduction policy for European HDVs.

Objective

Reduction and testing of GHG emissions from Heavy Duty Vehicles is split into two lots of work. The objectives of the two lots are to:

- *Lot 1:* assess the amount and reduction potential of Greenhouse Gas (GHG) emissions from Heavy Duty Vehicles (HDV), and to
- *Lot 2:* propose a method to quantify such emissions for whole vehicles as well as for vehicle components.

Lot 1: Strategy Support Objective

The service contract is to provide the Commission's services with **technical assistance** in the area of reducing GHG emissions from HDVs (passengers and freight).

+ Task 1: Vehicle Market and Fleet
+ Task 2: Fuel Use and CO_2 Emissions
+ Task 3: Technology
+ Task 4: Policy Assessment

Task 1: Vehicle Market and Fleet (AEA)

Objective: To identify and assess the vehicle markets and fleets in Europe

Inputs: from Task 3

Outputs: Information and data on existing European policy and legislation, HDV manufacturers, number and distribution of vehicle users, new market size and structure, existing fleet size and structure and onboard equipment.

Subtasks:

- Subtask 1.1: Summarising legislation and planned policies;
- Subtask 1.2: Characterisation of vehicle manufacturers;
- Subtask 1.3: Number and distribution of vehicle users, by Member State;
- Subtask 1.4: New vehicle market size and structure;
- Subtask 1.5: Existing fleet size and structure;
- Subtask 1.6: Energy consumption from on board equipment and vehicle adaptation to different mission profiles.

Task 2: Fuel Use and CO_2 Emissions (AEA)

Objective: To provide an assessment of the current fuel usage, and hence GHG emissions, from HDVs in EU27 member states (MS), disaggregated by sectors. Also to quantify how new HDV and likely future developments in HDV technology will impact on fuel consumption and GHG emissions.

Inputs: From Tasks 1 and 3

Outputs: A matrix indicating the current fuel use and CO_2 emissions for the EU27 member states (MS), disaggregated by sector and an assessment of the impact of new HDVs and likely future developments in HDV technology on these.

Subtasks

- Subtask 2.1: Fuel use and CO_2 emitted by the existing EU fleet;
- Subtask 2.2: Fuel consumption and CO_2 emissions for new HDVs;
- Subtask 2.3: Future development of fuel use and CO_2 emissions.

Task 3: Technology (Ricardo)

Objectives: Understand the technology that is and can be applied to heavy duty vehicles and the impact this will have on fuel consumption and GHG emissions.

Inputs: From Tasks 1 and 2

Outputs: A concise chapter with the final report containing the following: summary table of the key technologies, new and emerging technologies, the main technical and management solutions to monitor fuel consumption, illustration of variation of rolling resistance and aerodynamic drag with vehicle speed and results of the scenario analysis.

Subtasks

- Task 3.1: Survey Existing State of the Art;
- Task 3.2: Survey New and Emerging;
- Task 3.3: Survey Technical and Management Solutions;
- Task 3.4: Effect of Vehicle Speed on Fuel Consumption;
- Task 3.5: Ad Hoc Analyses;
- Task 3.6: Possible Reduction in HDV GHG Emissions.

Task 4: Policy Assessment (AEA/TEPR)

Objective: To provide a high level assessment (quantitative, where possible) of selected policy instruments that could be used to reduce GHG emissions from HDVs

Inputs: Task 1; literature and stakeholder comments

Outputs: An assessment of selected policy instruments in the form of a report providing summaries of the policies identified for investigation, qualitative assessment of a short-list of policies agreed with the EC and a final prioritised list of instruments.

Subtasks

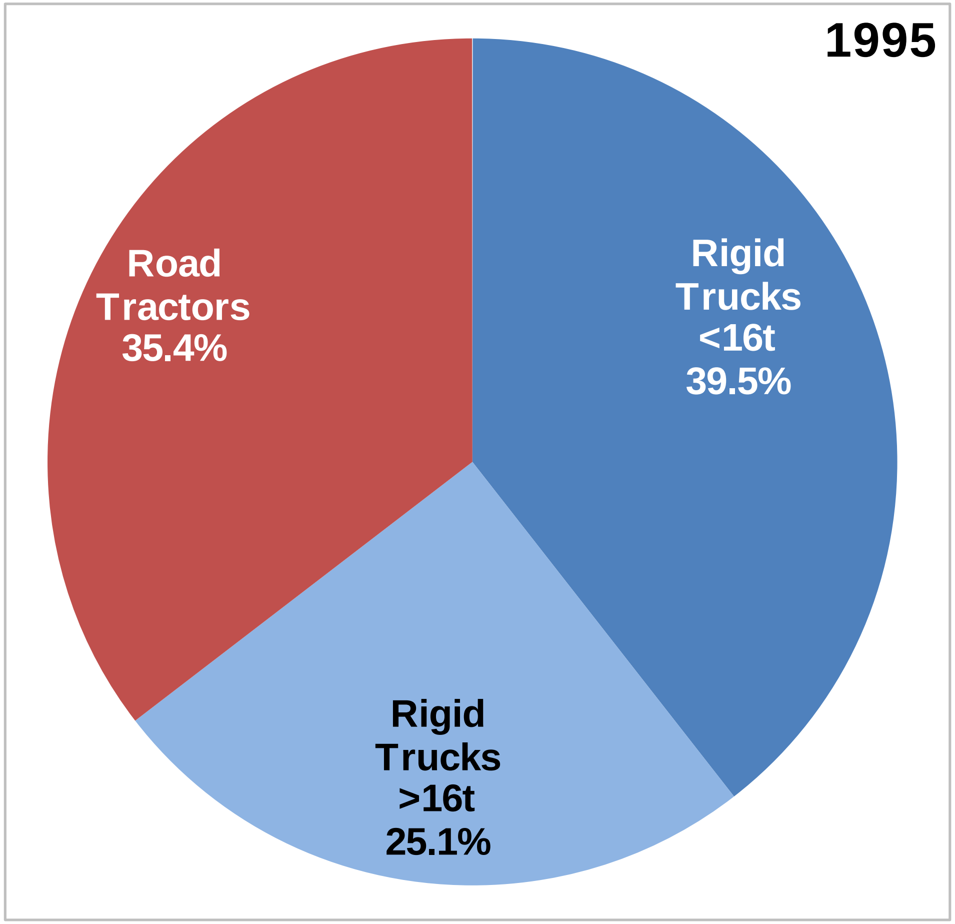
- Subtask 4.1: Collation of existing reports/information on current/planned policies;
- Subtask 4.2: Development of a long list of policy instruments;
- Subtask 4.3: Assessment of the impact of policy instruments against environmental, economic and social criteria;
- Subtask 4.4: Prioritisation of policy instruments and identification of need for further research.

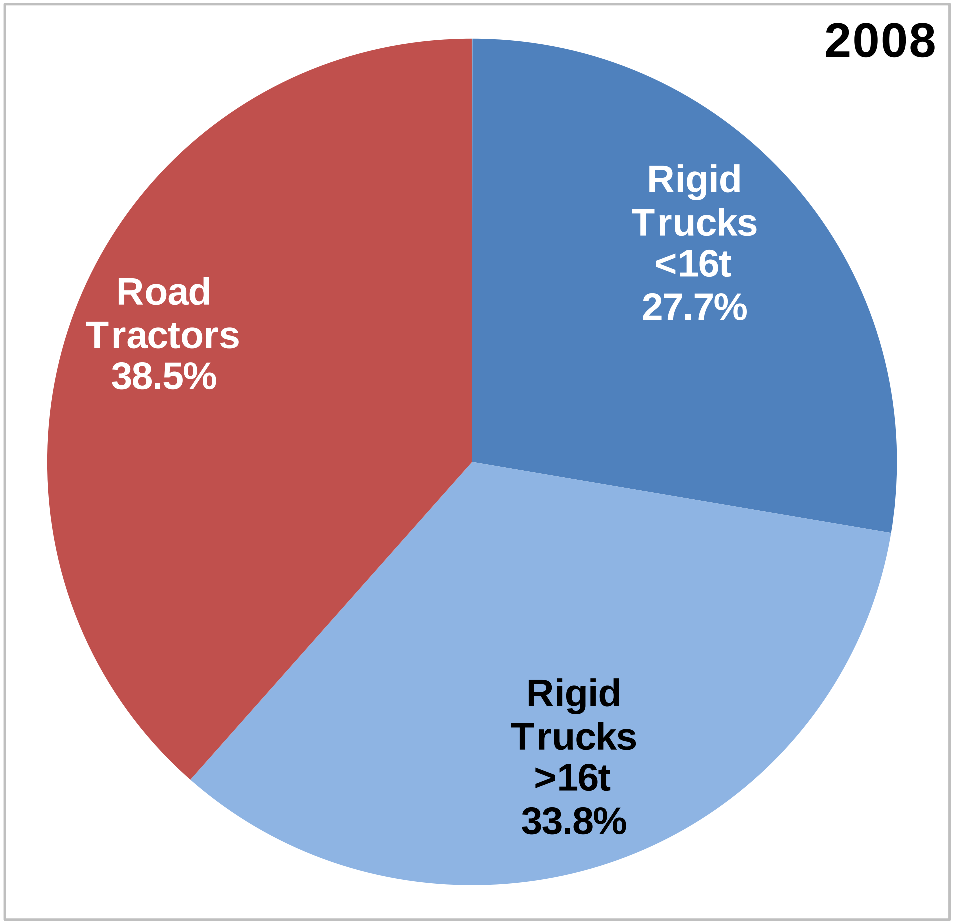
Task 1: Collection of Information and Data

- Review restricted to readily available information collected via
  - General literature review
  - Internet searches
  - Consultation with key stakeholder organisations (e.g. ACEA, IRU, T&E, UITP)
  - Questionnaires sent to all 27 EU Member States
  - Data purchased from data providers
- Key data sources:
  - EU wide general statistics from Eurostat
  - National Agencies and a Transport Ministries of each Member
  - ACEA for general information, plus assumptions on truck mission split
  - Purchased detailed EU trailer dataset from CLEAR
  - Essentially no data available from the major data European data providers for HDVs

Task 1.4: New vehicle market size and structure

- EU27 split of new registrations of rigid trucks and road tractors:



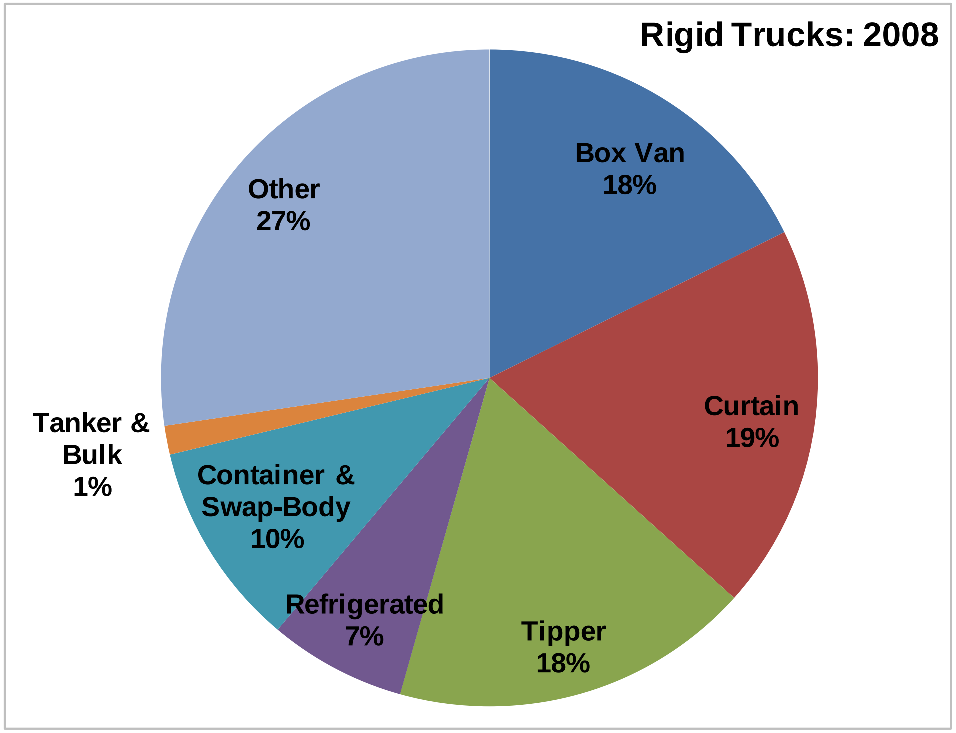


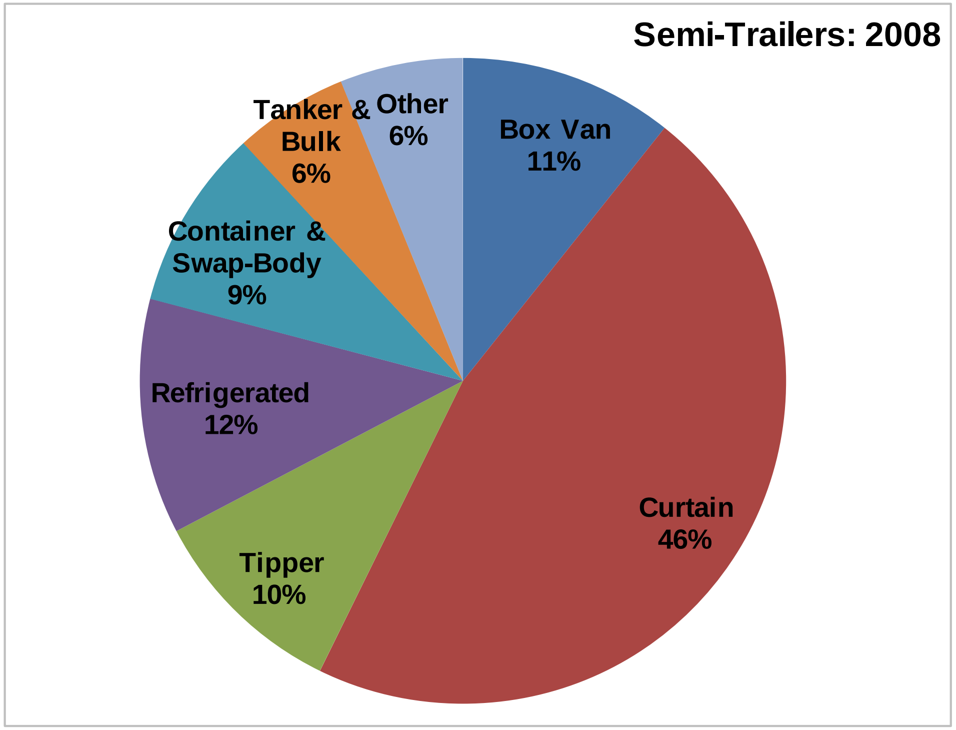
Source: Based on datasets from ACEA (2010) and Eurostat (2010)

Notes: AEA have estimated the split of registrations of new trucks by combining ACEA/Eurostat data

Task 1.4: New vehicle market size and structure

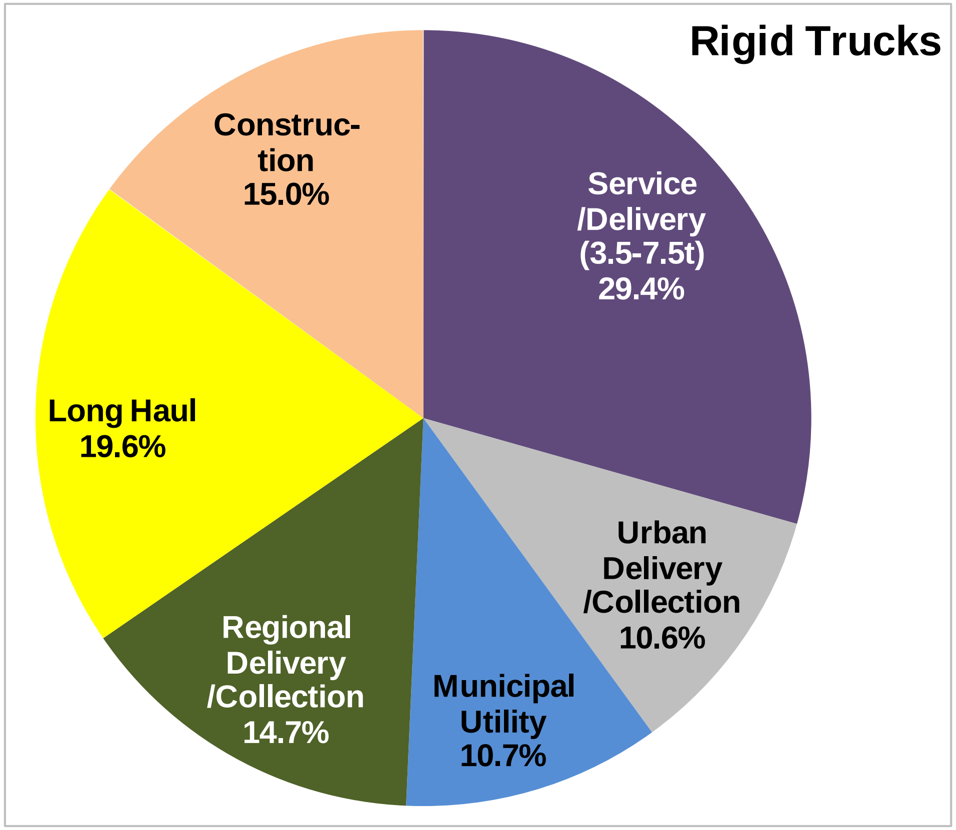
- EU27 new registrations of rigid trucks (VDA, 2010) and semi-trailers (CLEAR, 2010) by body type for 2008 :

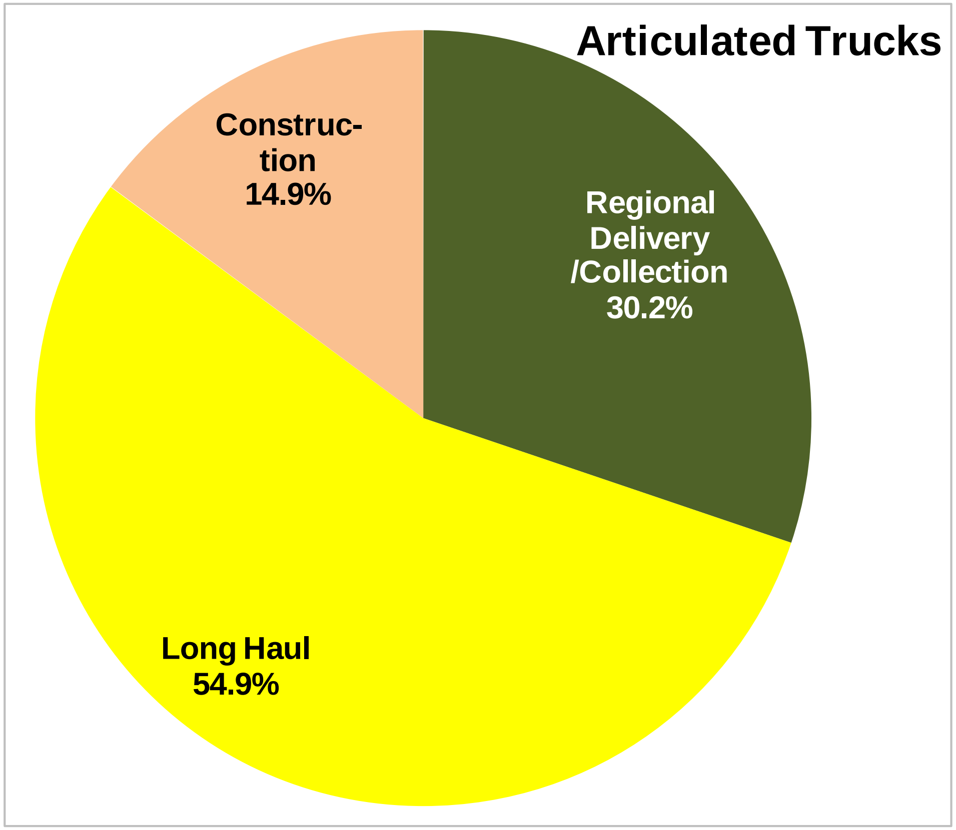




Task 1.4: New vehicle market size and structure

- Estimated EU Sales of Trucks by mission profile - average for sales between 2000 and 2009:

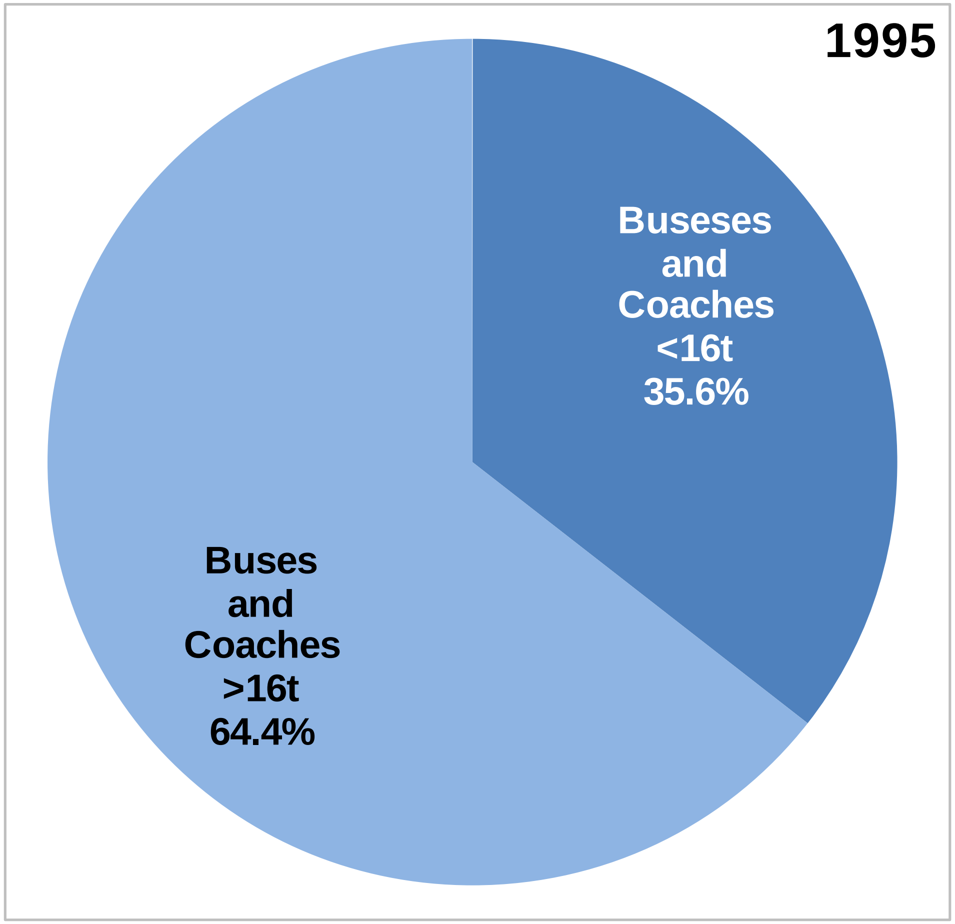


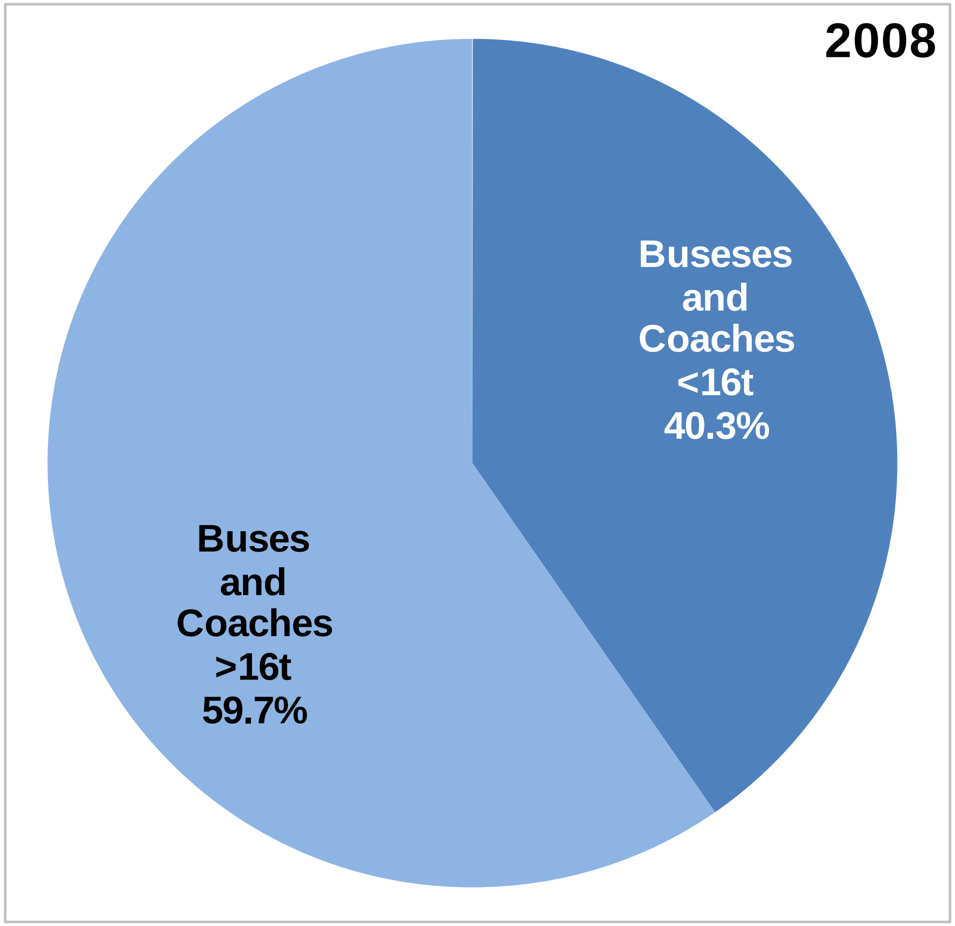


Source: AEA estimates based on dataset provided by ACEA (2010)

Task 1.4: New vehicle market size and structure

- EU27 split of buses and coaches by weight class:

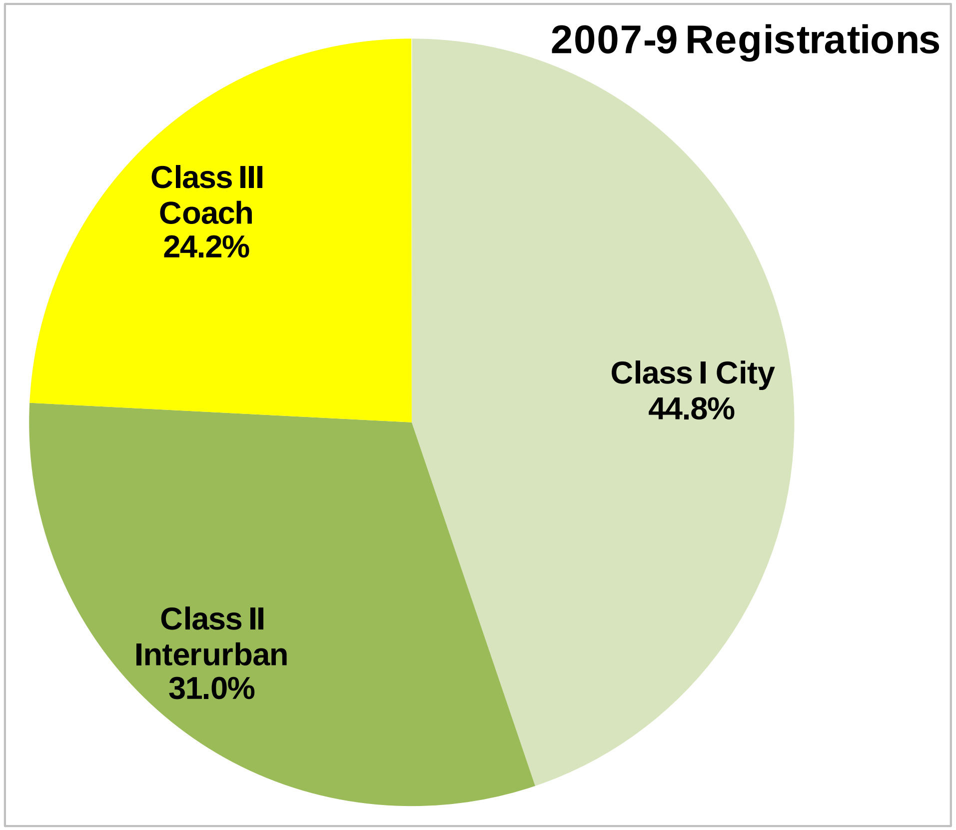




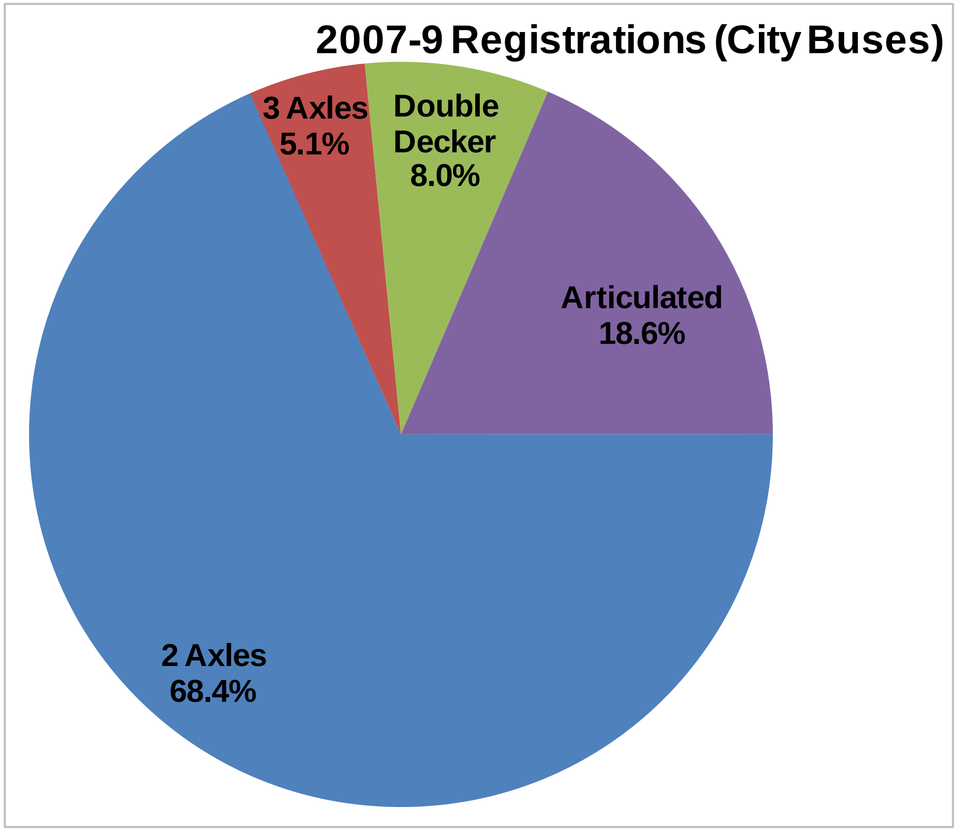
Source: Estimates based on ACEA (2010) dataset of registrations of new buses and coaches by weight class

Task 1.4: New vehicle market size and structure

- EU27 split of buses and coaches by class:



All Classes



Class I City

Source: Data provided by ACEA (2010) for registrations from 6 of its members of new buses and coaches (completed vehicles plus chassis supplied to bodybuilders)

Task 1.5: Existing fleet size and structure

- Summary
  - Road tractors/articulated vehicles are an increasing proportion of the EU truck fleet and account for the vast majority of total tonne-km. May be some inconsistency between EU-level statistics on road tractors numbers vs FLEETS database (30% higher) and information on new registrations (implies greater #).
  - Information from ACEA allowed the estimation of the split of trucks between different mission profiles with different activity and fuel consumption profiles
  - Refuse truck numbers estimated at 2%-3.5% of all trucks, but only maybe 2.2% to 3.8% of total truck CO_2 due to low annual km, despite high fuel consumption
  - Refrigerated rigid trucks and all trailers may account for around 7% and 10% respectively of total body types (and typically use 20% more fuel)
  - The coaches % of total bus and coach fleet appears to be relatively uncertain. Estimates vary between 37% (SDG, 2009) and 48% (FLEETS database).
  - European statistics also show that newer vehicles account for a greater proportion of total vehicle km compared to their overall numbers.
  - Use of alternative fuels is limited for trucks (and coaches), except in a few countries. For buses there is more widespread use.

Task 1: Overall Summary (1)

- EU market dominated by 7 major HDV manufacturers
  - 93% EU registrations and ~40% total worldwide production
  - ~25% bus and coach market served by other manufacturers and bodybuilders
- Trailer/bodybuilder market has 1000s organisations, 7 orgs. ~60% market
- HDV market highly complicated compared to LDVs
  - Final configuration (and performance) results from a chain of organisations
  - Final vehicle specification often bespoke/unique to fit particular application/cycle, with a wide variety of different auxiliary equipment utilised
  - Road tractor and semi-trailer pulled often owed by different organisations
- Data characterising the number and distribution of HDV operators across Europe is not collected in any standard format, and is very difficult to locate
  - 60% of the freight tonne km in the EU are associated with longer distance trips
  - Most freight operators smaller in size, with 85% having fewer than 10 vehicles
  - HoR operations >85% tonne km, travel longer distances vs Own Account. HoR operations also purchase and own the majority of road tractors (# increasing)
  - Total fleet and average fleet size of bus companies > coaches

Task 1: Overall Summary (2)

- ACEA information allowed the estimation of the split of heavy duty trucks between different mission profiles with different activity and fuel consumption profiles
- Clear differences in distribution vehicles by age between trucks and buses/coaches
    - significant age variation between Northern Europe and South, Eastern Europe
    - Average lifetime of trucks in EU >10 years vs ~15 years for buses and coaches
- Alt. powertrains not significant for trucks, but more for buses (in some MS)
    - Natural gas is the most used alternative in the EU15 (not in EU12)
    - Significant number of the EU12 states have electrically powered trolley-bus systems
- Little information is available on the second hand vehicle markets for HDVs.
    - => does suggest movement of older used HDVs vehicles from major EU economies to southern Europe and also the newer EU Member States

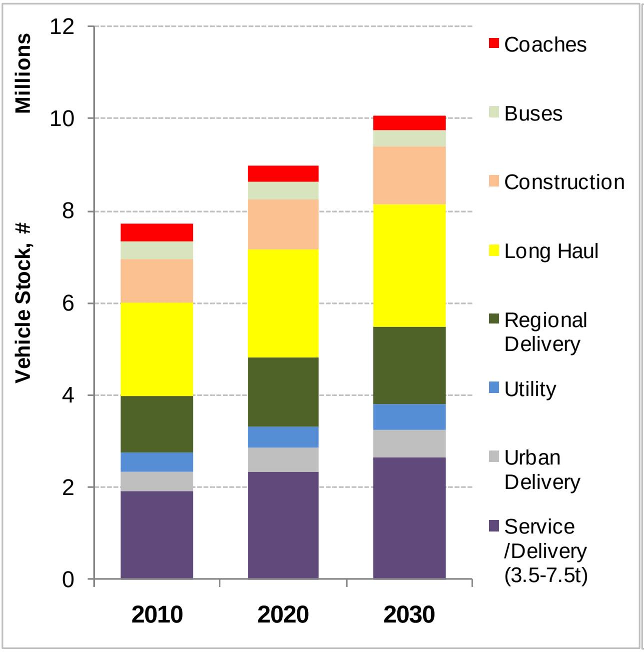
Task 2: Fuel Use and CO_2 Emissions
Summary

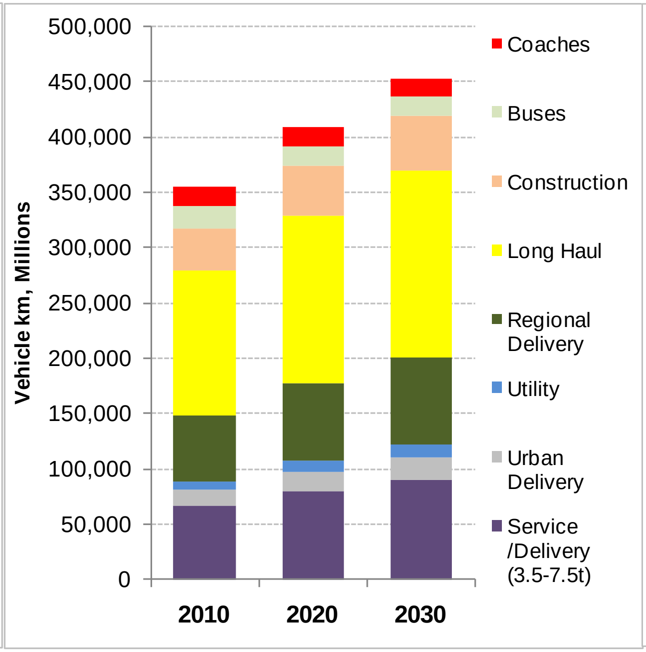
- Developed stock-model based calculations of emissions by Member State in order to estimate disaggregated emissions split for existing and future fleet to 2030
- BAU technology assumptions for new HDVs include:
  - General improvement 0.3%/a for powertrain, 0.2-0.3%/a for vehicle (body/other)
  - 3% efficiency penalties in 2013 (Euro VI) and in 2018 (*speculative* Euro VII)
  - Urban/regional usage: stop-start increase to 95%, hybrid 5% by 2030
- Results of calculations under BAU scenario shows that trucks account for almost 85% of energy/CO_2 in 2010, rising to almost 90% by 2030
- Long-haul trucks account for over 43% of truck energy consumption and CO_2 emissions in 2010 staying approximately constant to 2030 under BAU conditions
- Overall energy consumption and CO_2 emissions may increase by 15% by 2030 (+21% for trucks, -21% for buses and coaches)
- Refrigerated transport accounts for an estimated 6-7% total energy/CO_2

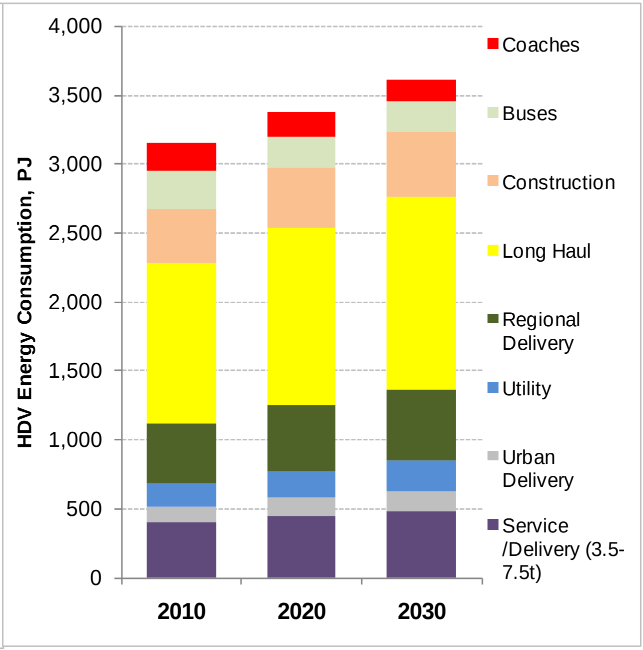
Task 2: Fuel Use and CO_2 Emissions

BAU Stock, Activity and Fuel Use Projections

- BAU estimates for the evolution of vehicle stock, vehicle km and energy consumption to 2030 by HDV mission category:



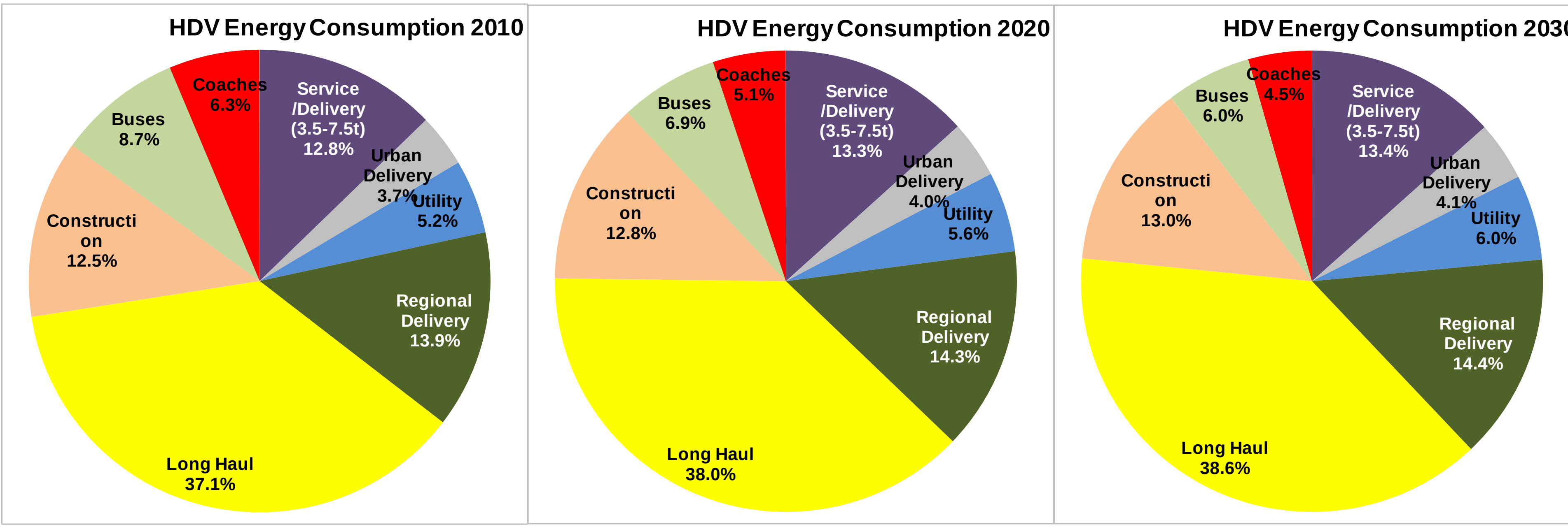




- Results illustrate
  - Importance of long-haul activity in total emissions due to higher activity levels
  - High fuel consumption increases energy consumption for Utility category vs vkm
  - Service/delivery and urban delivery vehicles relatively low impact vs numbers
  - Buses and coaches share decreasing to 2030

Task 2: Fuel Use and CO_2 Emissions
BAU Breakdown of Energy Consumption Projections

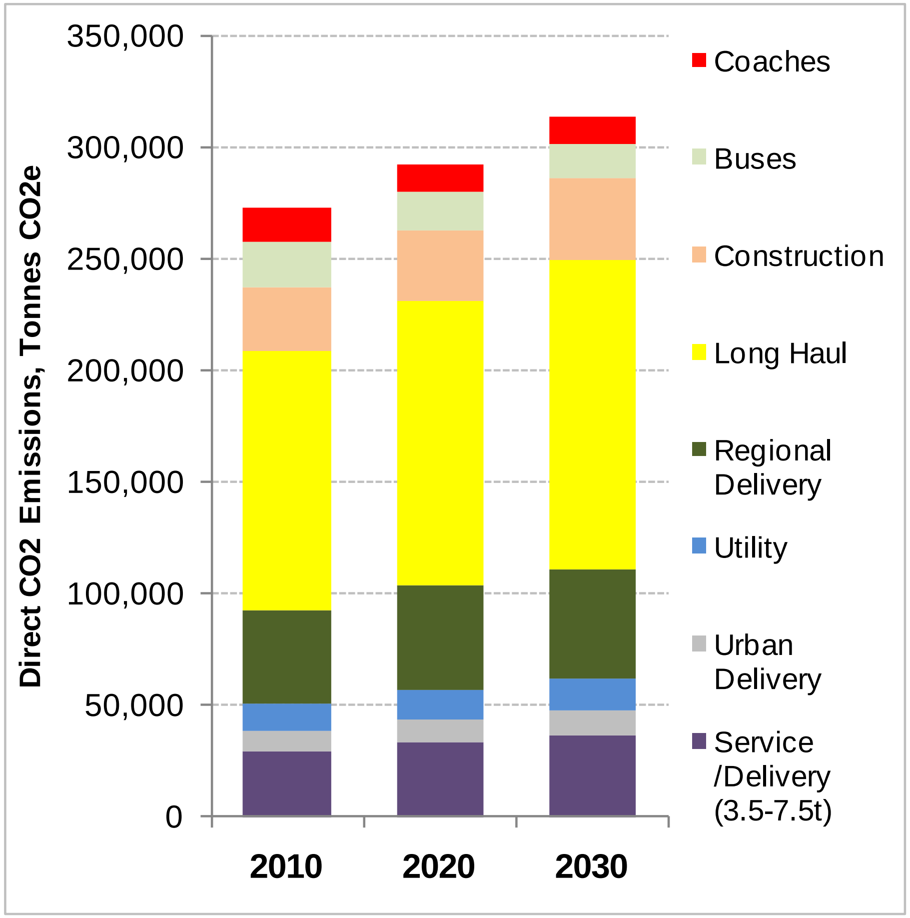
- BAU estimates for the evolution of energy consumption to 2030 by HDV mission category:

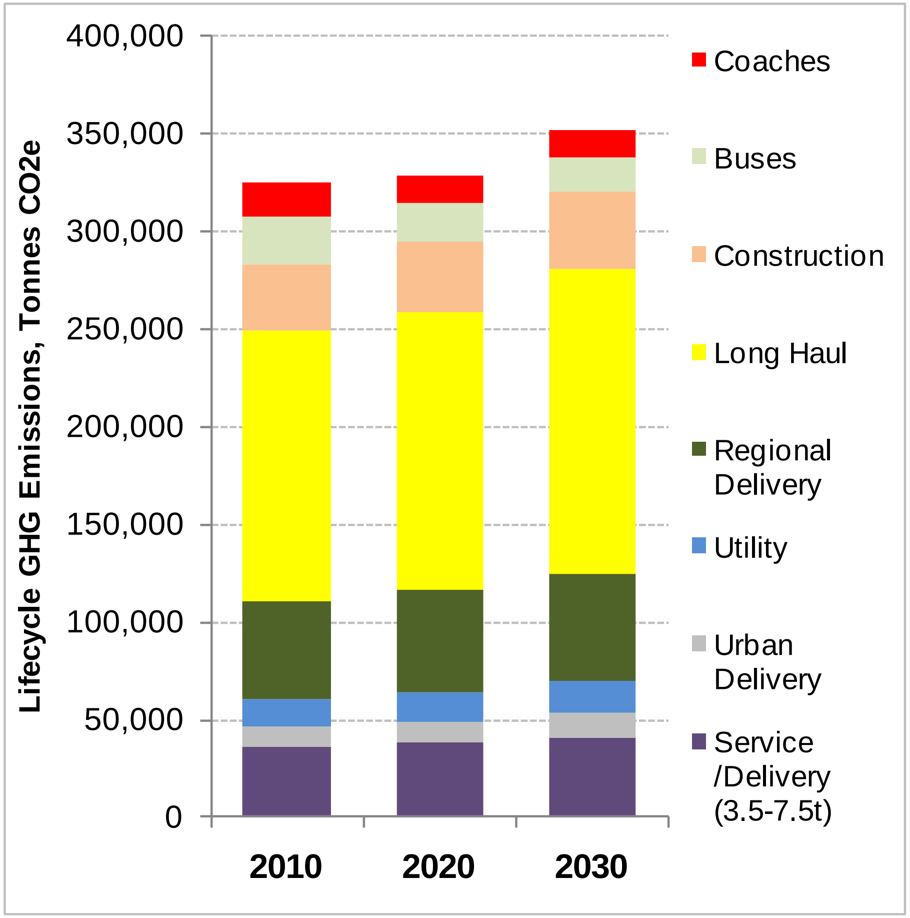


- Results illustrate
  - Very little change in proportions of different mission categories over time in BAU case (except decreasing proportion of bus and coaches)
  - Overall increase between 2010 and 2030 of 15% in energy consumption for all HDVs = 21% increase for trucks and 21% *decrease* for buses and coaches
  - Corresponding stock changes are +31% total, +35% truck and -9% bus/coach

Task 2: Fuel Use and CO_2 Emissions
BAU GHG Emissions Projections

- BAU estimates for the evolution of Direct and Lifecycle CO_2 emissions to 2030 by HDV mission category:

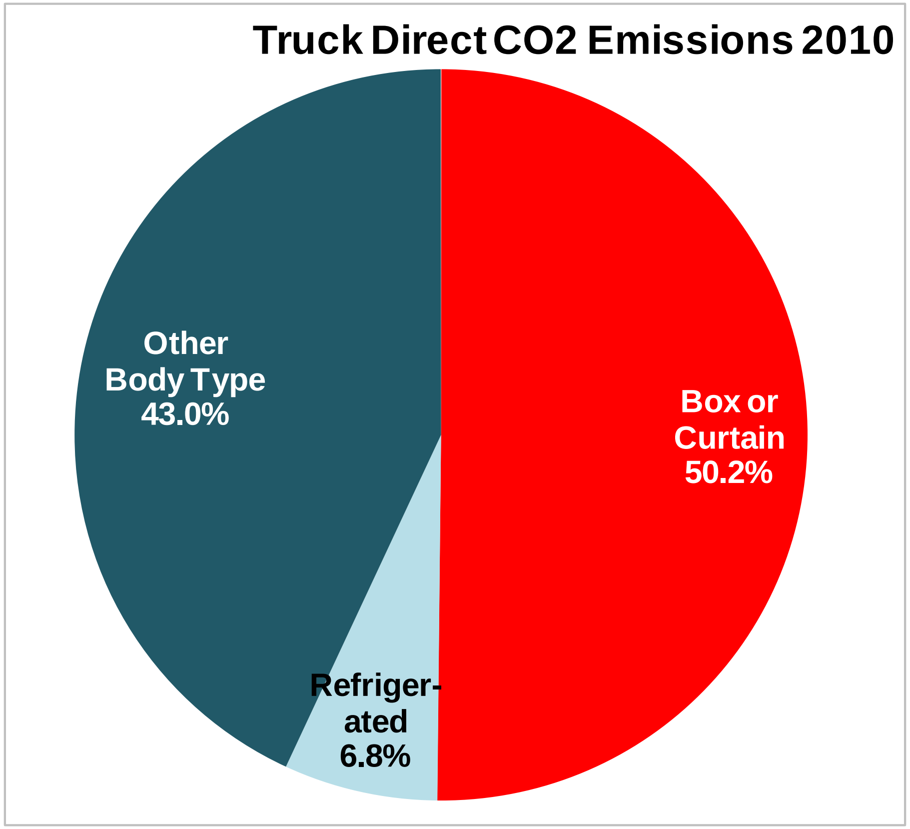


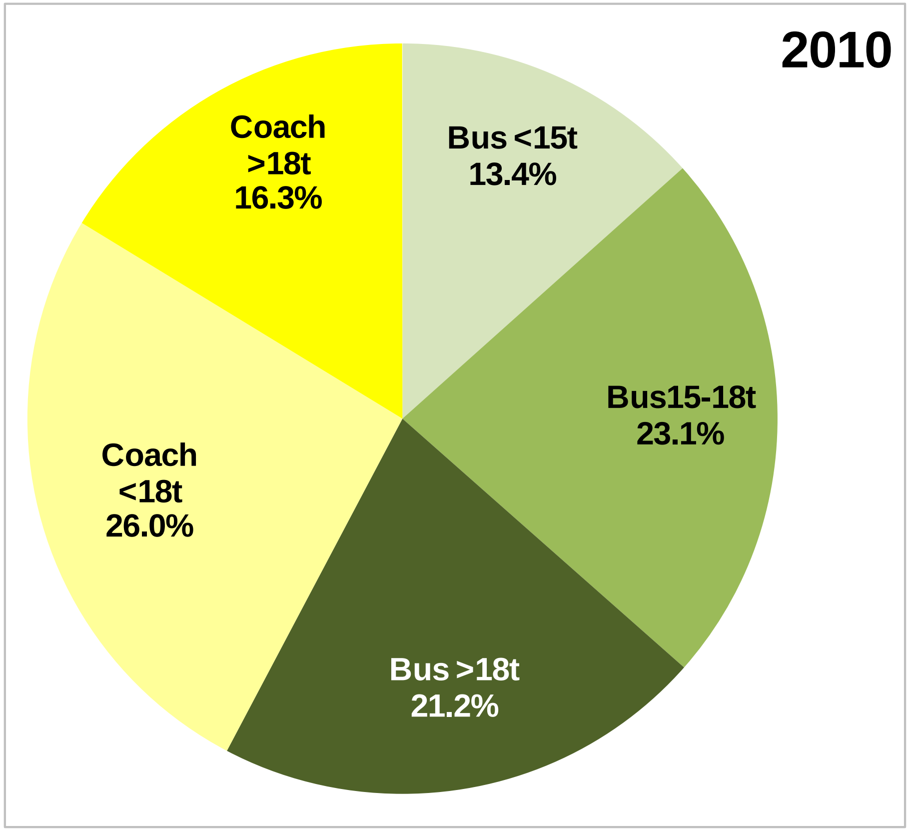


Notes: Lifecycle emissions include existing biofuel/GHG reduction commitments to 2020

Task 2: Fuel Use and CO_2 Emissions
BAU GHG split by body type

- BAU estimates for the energy consumption truck body type and bus/coach weight class:





- Results show
  - Very little change 2010 to 2030 for the BAU case.

Task 3: Technology (Ricardo)

Objectives: Understand the technology that is and can be applied to heavy duty vehicles and the impact this will have on fuel consumption and GHG emissions.

Inputs: From Tasks 1 and 2

Outputs: A concise chapter with the final report containing the following: summary table of the key technologies, new and emerging technologies, the main technical and management solutions to monitor fuel consumption, illustration of variation of rolling resistance and aerodynamic drag with vehicle speed and results of the scenario analysis.

Subtasks

- Task 3.1: Survey Existing State of the Art;
- Task 3.2: Survey New and Emerging;
- Task 3.3: Survey Technical and Management Solutions;
- Task 3.4: Effect of Vehicle Speed on Fuel Consumption;
- Task 3.5: Ad Hoc Analyses;
- Task 3.6: Possible Reduction in HDV GHG Emissions.

Task 3: More technical features appear on trucks than on buses and they vary across regions aside from engine technology which is similar

Task 3.1 – Survey of Existing State of the Art Technology

- The survey has revealed that there are numerous technologies available for use on all HDVs
- Many more technical features are employed on trucks compared to buses and coaches
- Engine technologies across Europe, USA and Japan are very similar but there is little emphasis on vehicle technologies particularly on city buses than for the freight segment
- While city buses and coaches have similar engine technologies transmission types are very different
- Only coaches appear to employ ITS features such as cruise control as standard with options for adaptive cruise control and tyre pressure monitoring
- The future introduction of Euro VI emissions legislation in Europe is likely to require the use of both SCR and EGR to meet limits which will incur a fuel penalty in the region of 3% over Euro V

Task 3: There are a large number of technologies which can be applied to HDVs but benefits are highly dependent on vehicle duty cycle

Task 3.2 – Survey of New and Emerging Technology

+ New and emerging technologies for the reduction of greenhouse gas emissions from HDVs include those which are optional on new vehicles and which currently have only niche market penetration
+ Technologies were considered in four areas: Engine, Driveline, Vehicle and ITS/ICT
+ Technologies in the drivetrain and vehicle categories can have the largest impact on fuel consumption
+ Fuel consumption benefit is highly dependent on vehicle duty cycle – while some technologies can provide benefit across a range of vehicle duty cycles others have much greater benefits for some and none for others
+ For vehicles with an urban duty cycle with frequent stop / start behaviour hybrid vehicles offer the highest benefit of between 20% and 30%
+ For heavy duty vehicles aerodynamic aids such as aerodynamic trailers can offer the greatest benefits of circa 10% reduction in fuel consumption
+ Benefits of technologies are not always cumulative – some technologies target the same area and as such the sum will be less than individual parts

Task 3: Engine based technologies can have a maximum benefit of 30% for modification to conventional vehicles or 100% with alternative power

Task 3.2 – Survey of New and Emerging Technology

Engine Technology	Benefit	Comments
Dual Fuel Systems	10 – 20% - benefit dependent on duty cycle	Can be retro-fitted, CNG infrastructure is not universally developed
Variable flow / Electric Water pump	0.7% for variable flow 1 – 4% electric	Electric pumps only applicable to new engine design, requires fail safe design
Variable speed oil pump	1 – 3% possible	Impact of pump failure is severe
Hydrogen fuel cells	100% - tailpipe reduction only	Limited infrastructure, weight of overall system, only demonstrator HD vehicles
Electric Vehicles	100% tailpipe emission reduction	Lower payload than diesel, limited range, limited to 12t GVW currently
Stop / Start Hybrid	0 – 30%, average 6%, best for urban cycles	Not suitable for vehicles requiring power when stationary
Brake Energy storage	4 – 10% for long haul; 20 – 30% for urban cycles	Additional weight and technology immaturity
Mechanical Turbocompound	3 – 5% - best for long haul applications	Complicated gear drive required, can affect aftertreatment efficiency
Electrical turbocompound	Max 10%, average 3%	In development, added complexity for energy storage and control
Bottoming Cycles	3 – 6% depending on cycle	Research phase, added complexity and package challenge
Controllable Air Compressor	1.5% average – best for long haul applications	Clutch must fail safe, less compressor idle time in stop / start driving
Electric Engine Accessories	0 – 8%	Some systems unproven on HDD; long haul expected to offer greatest benefit

Task 3: Driveline based technologies can reduce tailpipe CO_2 emissions by up to 30% for frequent stop/start duty cycles

Task 3.2 – Survey of New and Emerging Technology

Driveline Technology	Benefit	Comments
Automated Transmission	7 -10% replacing manual with AMT	Benefits greatest for untrained driver and will decrease with increasing driver skill
Full Hybrid	7% long haul, 20% urban	Can lead to a reduction in payload, requires mechanic training due to high voltage levels
Flywheel Hybrid	20 – 30% for urban cycles Inter-city ~ 10%	Better for frequent stop/start cycles, technology immature for commercial vehicle applications

Task 3: Vehicle based technologies can reduce fuel consumption by up to 20% with aerodynamics giving most benefit to long haul applications

Task 3.2 – Survey of New and Emerging Technology

Vehicle Technology	Benefit	Comments
Low Rolling Resistance Tyres	Up to 5%. Greatest for long haul applications	Depends on number of tyres replaced
Single Wide tyres	2% for single axle and 6 – 10% for whole vehicle	Legislated limitations on use on tractor drive axles for vehicles >40t
Automatic Tyre Pressure Adjustment	Estimated 7 – 8%	Systems expensive
Aerodynamic Trailers	Average 10%	Greatest benefit for vehicles with high average speed
Aerodynamic Fairings	0.6 – 4.8% depending on fairing and vehicle type and duty cycle	Can have an adverse impact on fuel consumption if set incorrectly
Active Aero	Up to 8.7%	Early stage technology; Most applicable long haul applications
Lightweight Materials	1.7% on volume limited applications and 4.2% on weight limited	Increased cost, more energy intensive manufacture
Alternative Fuel Bodies	10 – 20% depending on body power system replaced	Not applicable to all applications, makes most sense for hybridised vehicles

Task 3: ITS/ICT based technologies aim to improve driver behaviour and can bring benefits of up to 10% depending on driving style

Task 3.2 – Survey of New and Emerging Technology

ITS/ICT Technology	Benefit	Comments
Predictive Cruise Control	2 – 5% but will vary with route	Small potential increase in journey time, benefit subject to route
Vehicle Platooning	~20% for motorway speeds	Liability of automated vehicle control, infrastructure requirement, implications for other vehicles on road – not likely before 2030
Green Zone Indicator	5 – 10%	Benefits variable and lower with trained drivers
Smart Alternator, Battery Sensor & AGM Battery	Estimated at 1 – 2%	In market on passenger cars
Acceleration Control	Up to 6% depending on driving style	Greatest benefit expected in applications with frequent acceleration, must permit overtaking
Governing Speed Control – Progressive Shift	1 – 4% depending on driving style	Max benefits in urban environment
Eco Roll – Freewheel Function	~1% - expected to be highly dependent on application	Requires fail safe mode

Task 3: There is no mandatory requirement to monitor fuel use in the EU and as such a number of different systems are available

Task 3.3 – Survey of Technical and Management Solutions

+ There are no mandatory requirements to monitor and report fuel use for HDVs within the European Union
+ Accurate management of fuel requires data capture that can identify and record the three critical influences: 1) the driver, 2) the vehicle and 3) the journey
+ The collection of data can be either a manual paper based system or through the employment of telematic systems
+ There are no set rules determining the applicability of individual systems to an HDV operator

Task 3: A reduction in vehicle speed of 10km/h for HDV can reduce fuel consumption by 6% and reduce operating costs by 1.5%

Task 3.4 – Effect of Vehicle Speed on Fuel Consumption

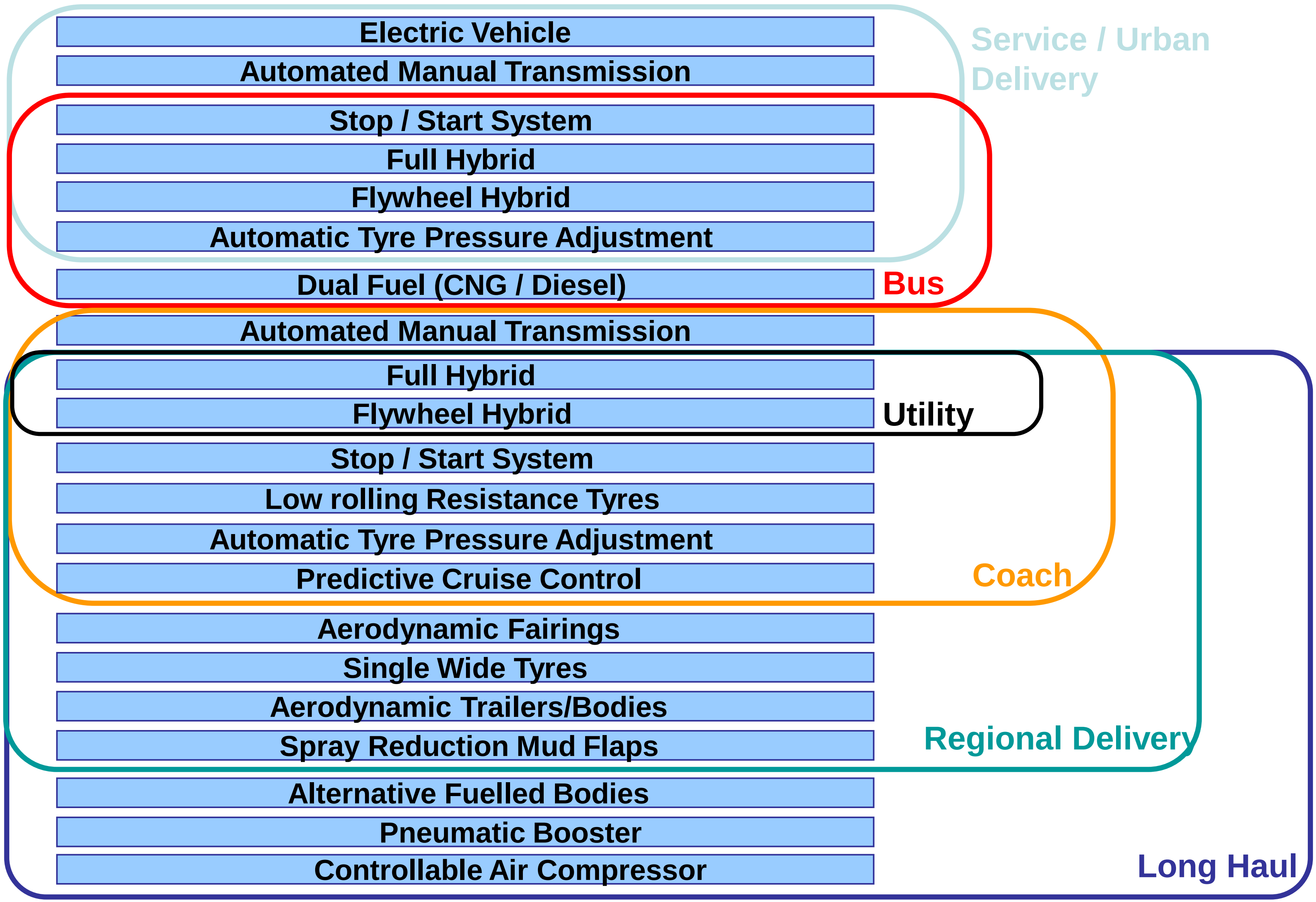
+ Variations in speed for medium duty vehicles from 70km/h to 90km/h can result in a 21% increase in fuel consumption
+ A reduction from 90km/h to 80km/h maximum speed for heavy duty commercial vehicles can result in a 6% reduction in fuel consumption
+ Fuel represents the single largest cost for an operator at 30% of operations for a 40t articulated vehicle
+ A 5% reduction in fuel consumption would result in a 1.5% reduction in operating costs for a typical operator of long haul vehicles, which can amount to significant monetary sums
+ Safe and fuel efficient driving has little impact on journey times, however a 10km/h reduction in maximum vehicle speed could have implications on increased journey times requiring additional driver rest periods resulting in longer journey times

Task 3: Two different scenarios have been modelled to assess the impact on fleet CO_2 emissions of technology uptake over a BAU scenario

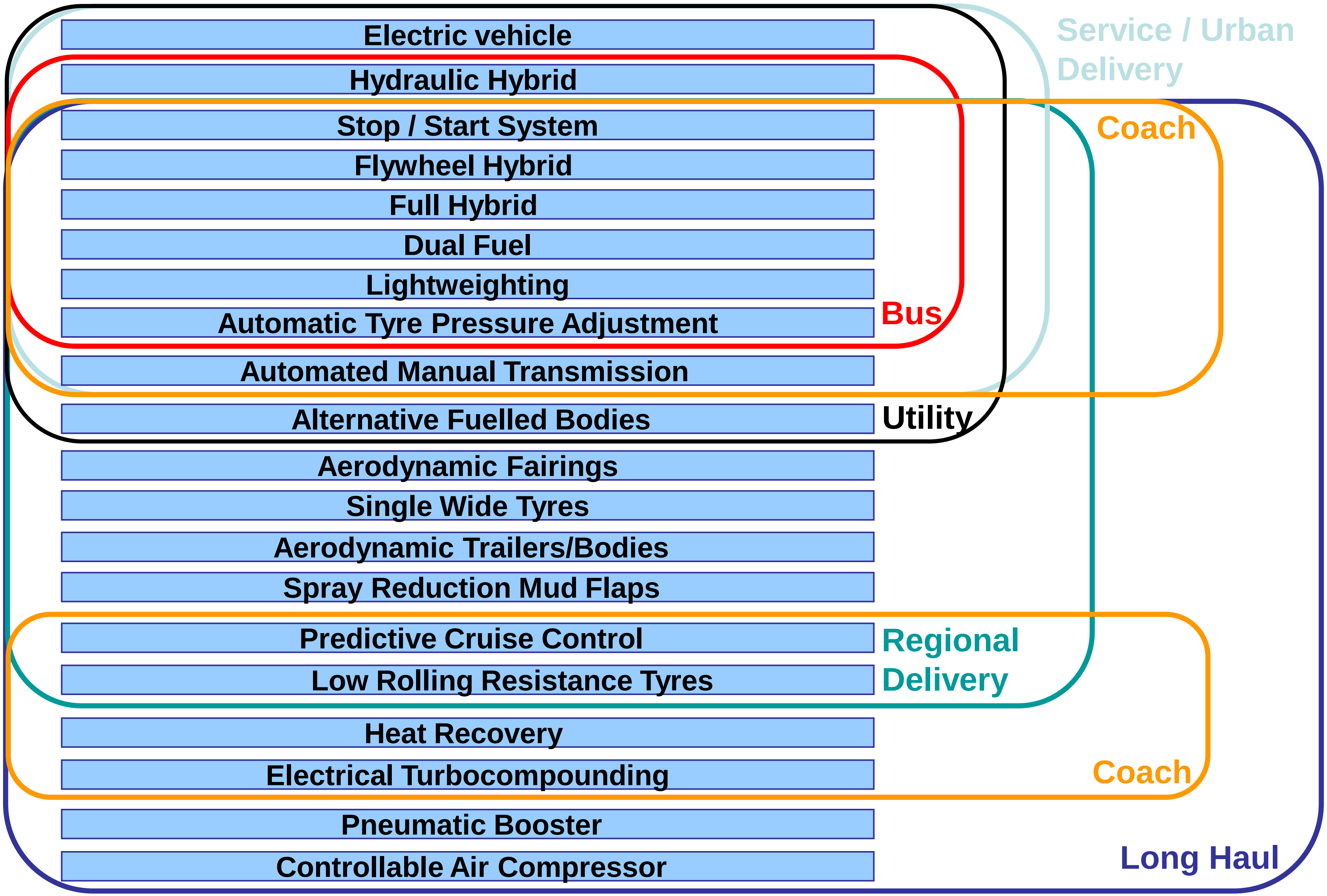
Task 3.5/6 – Assessment of possible future reduction in total EU fuel consumption and GHG emissions from HDVs

- Two different scenarios have been developed which model differing rates of technology uptake:
  - *Cost Effective:* Mainly technologies which are have a commercially acceptable payback period
  - *Challenging:* More aggressive rate of uptake of technologies and also including those which have a less attractive payback period
- Uptake rates for the technology were modelled for 8 different vehicle mission profiles as technology benefit and applicability varies with vehicle duty cycle
- Results are compared with the output of the Business As Usual (BAU) scenario

Task 3: Technology Scenario 1 – Cost Effective scenario which assumes take up of technology with good payback period

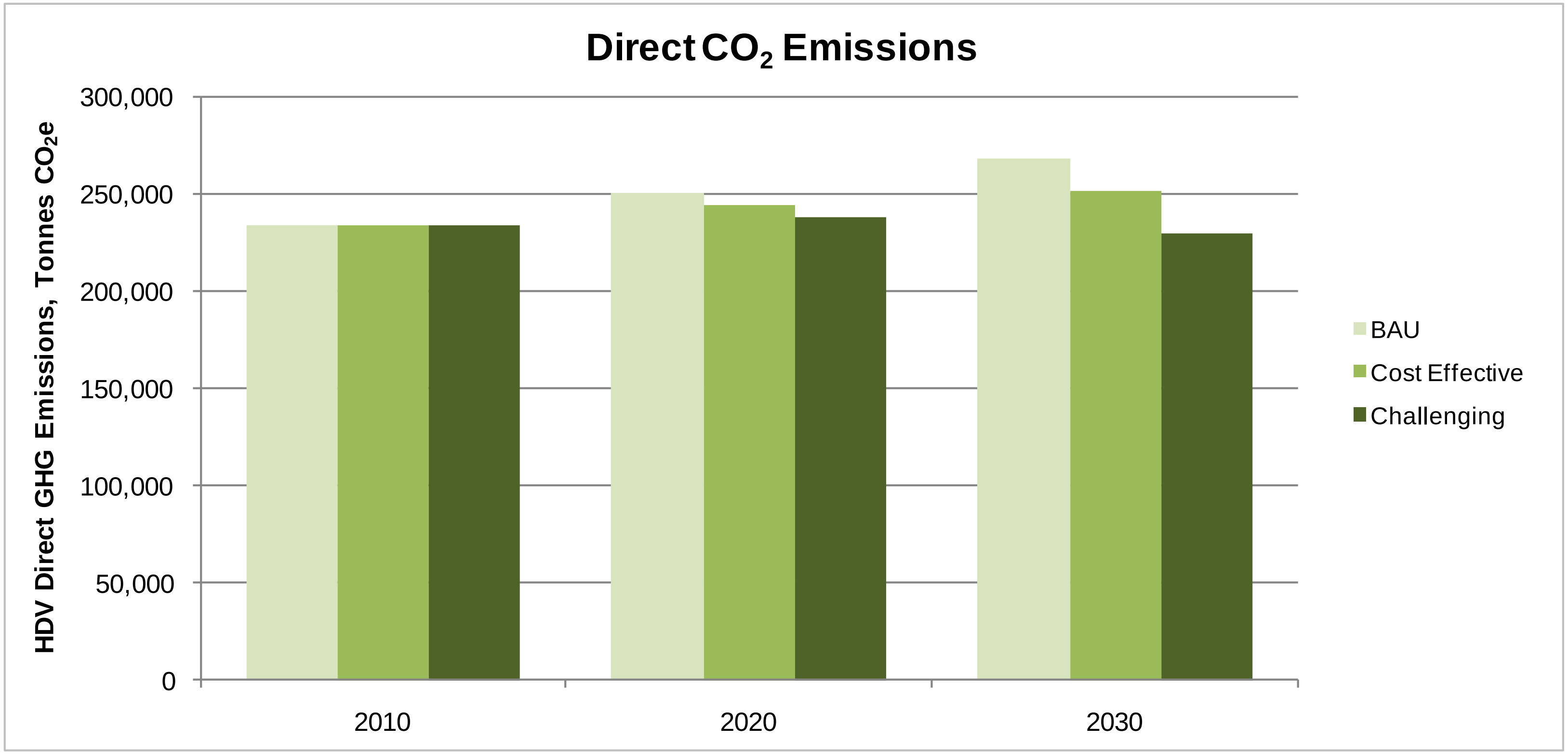


Task 3: Technology Scenario 2 – Challenging scenario which assumes take up of technology with longer payback periods



Task 3: In order to reduce HDV CO_2 emissions below 2010 levels by 2030, challenging technology uptake rates are required

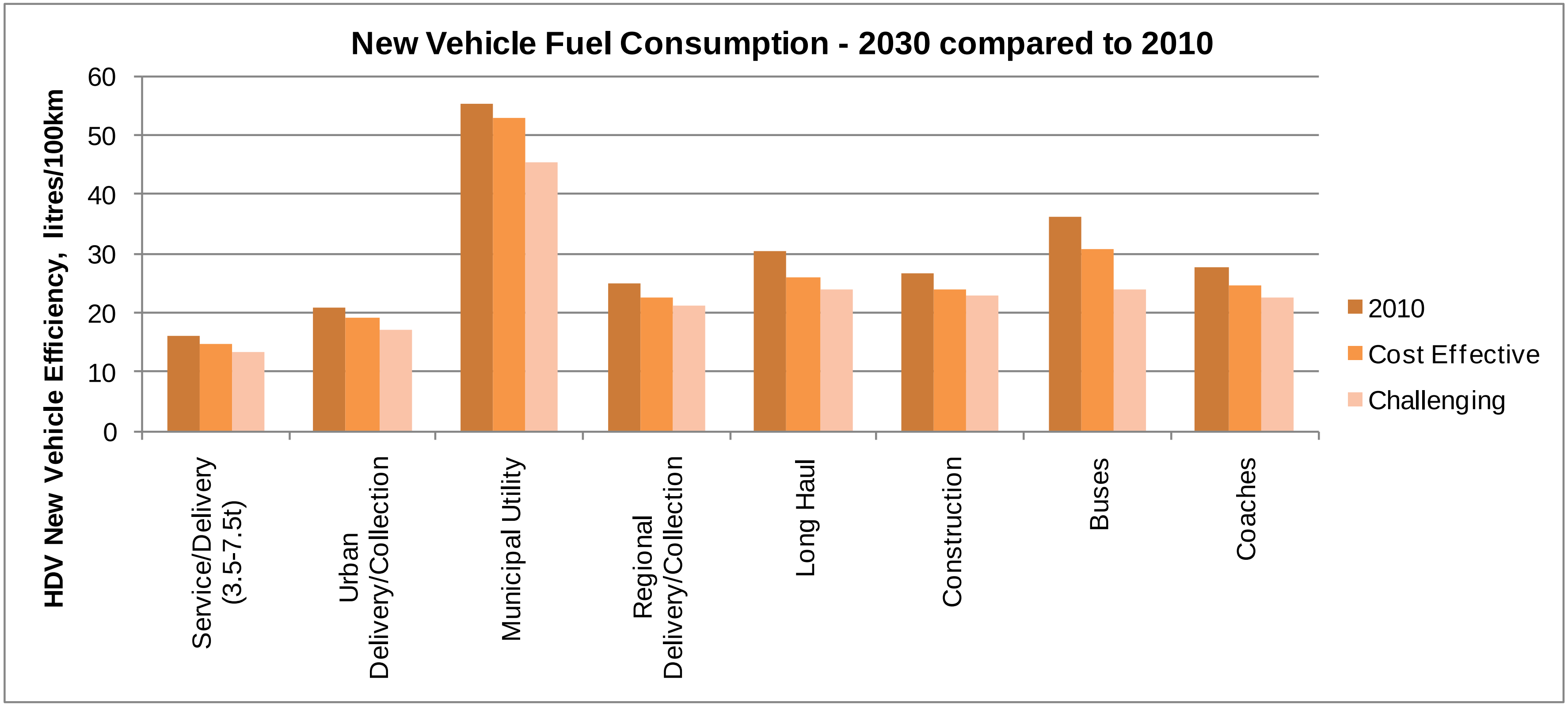
Task 3.5/6 – Assessment of possible future reduction in total EU fuel consumption and GHG emissions from HDVs



- Only through the uptake of challenging levels of technology can the continual increase in both heavy duty lifecycle GHG and direct CO_2 emissions be reduced over today's level
- Through technology uptake as proposed by the challenging scenario heavy duty vehicle fleet lifecycle GHG emissions can be reduced by 7.3% and direct CO_2 emissions by 2%

Task 3: Greatest reduction in fleet vehicle efficiency is 11% for Long Haul vehicles in Cost Effective and 19% for Urban Delivery in Challenging

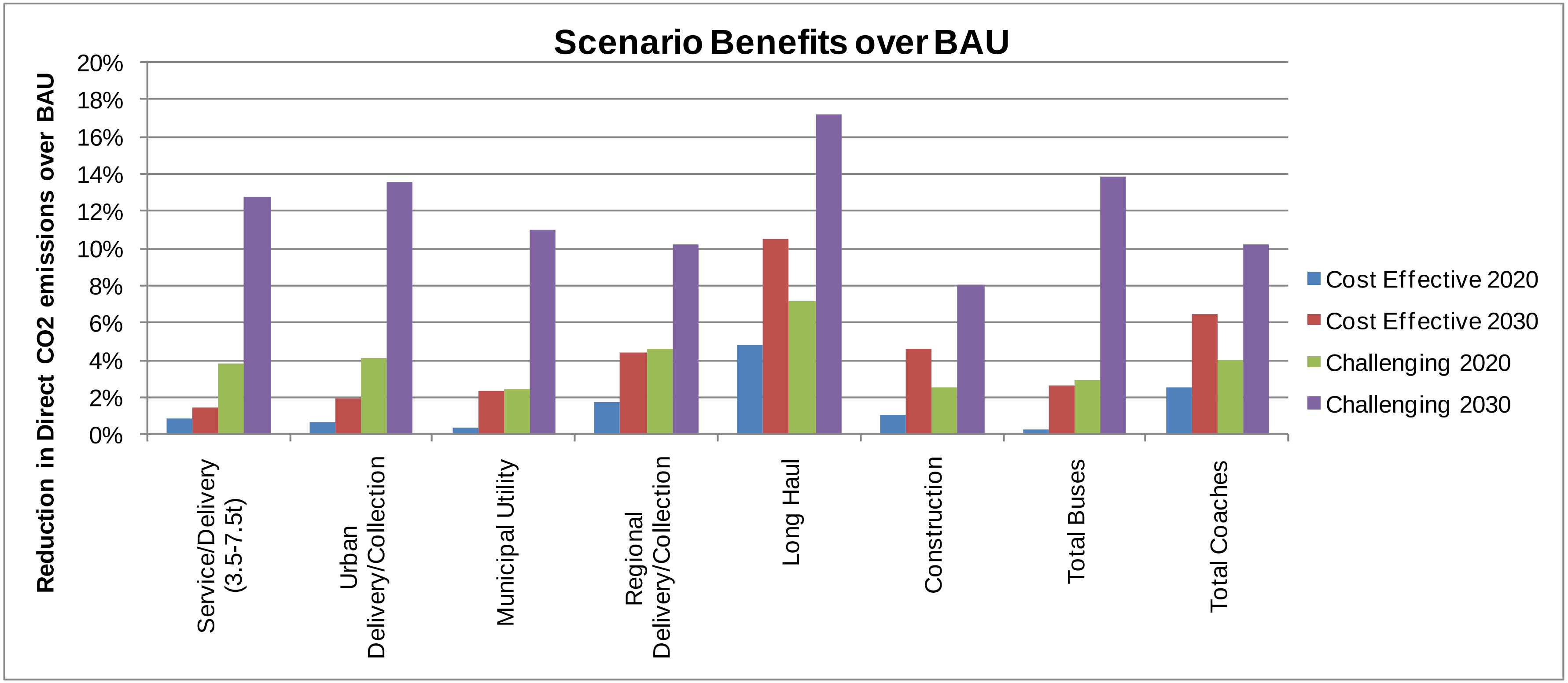
Task 3.5/6 – Assessment of possible future reduction in total EU fuel consumption and GHG emissions from HDVs



- The Cost Effective technology scenario results in greatest truck fleet fuel consumption reduction of Long Haul vehicles of 15.6%. The bus fleet reduces fuel consumption by 18.7%
- The Challenging technology scenario results in greatest reduction in truck fleet fuel consumption for Urban Delivery vehicles at 23.7%. The bus fleet reduces fuel consumption by over 33%

Task 3: Highest improvements in new vehicle efficiency are 15% for Long Haul vehicles in Cost Effective and 34% for Buses in Challenging

Task 3.5/6 – Assessment of possible future reduction in total EU fuel consumption and GHG emissions from HDVs



- The Cost Effective technology scenario results in greatest decrease in new vehicle fuel consumption of 15.3% for Long Haul Vehicles
- The Challenging technology scenario results in greatest reduction in new vehicle fuel consumption for Buses of 33.8%

Summary and Final Conclusions (1)

- HDV market is complex with significant diversity in final vehicle specification and performance/use. European manufacturers dominate the EU market and are significant/influential players globally
- Vast majority road freight associated with longer distance trips transported primarily by hire or reward operators with relatively small fleet sizes
- HDVs are load carrying vehicles with considerable range in size/application
  - Metrics of fuel efficiency or GHG emissions appear to be best related to work performed, e.g. fuel cons. per unit payload (i.e. tonnes, m^3 or passengers)
  - Policy analysis suggests that any developed standards would also best take into account specific duty cycles for different applications or classes of HDV
  - **A firmer conclusion on this will result from the LOT 2 investigation**
- Results of the technology development /uptake modelling analysis show:
  - In the BAU Scenario, energy consumption / GHG emissions rise 15% by 2030
  - Analysis shows only by challenging technology uptake levels can the continual increase in GHG emissions be reduced below 2010 levels by 2030

Summary and Final Conclusions (2)

- A high level policy assessment of identified instruments applicable to the EU has been carried out following the EC Impact Assessment Guidelines.
  - A summary assessment of shortlisted policies has been provided
  - Prioritisation not possible as cost-effectiveness and GHG reduction potential of each instrument depends on detail of the instrument, which was outside the project scope
- The project scope did not include modelling of a range of important options that may offer significant opportunities for further FC/GHG reductions
  - Improved Auxiliaries (e.g. refrigeration) and Fuel Measures (e.g. uptake and savings from the use of biofuels and infrastructure considerations for alternative fuels)
  - Regulations on vehicle dimensions and weight – e.g. longer and heavier vehicle (LHV) combinations may have a beneficial role to play, but this depends on benefit erosion by the size of potential rebound effects due to reduction in transport costs
  - Possible impacts of speed controls or reductions on heavy duty vehicle fleet fuel consumption
  - Road infrastructure measures, such as measures improving capacity, reducing inclines and bottlenecks
  - Operational measures, including ITS
- These also need to be taken into account when considering the design of future policy and regulation to reduce greenhouse gas emissions

AEA

Nikolas Hill
Knowledge Leader – Transport Technologies and Fuels

AEA
The Gemini Building
Fermi Avenue
Harwell, Didcot,
OX11 0QR
United Kingdom

Tel: +44 (0)870 190 6490
E: nikolas.hill@aeat.co.uk
W: www.aeat.co.uk