EU Transport GHG: Routes to 2050?

Regulation for vehicles and energy carriers

Part I – General issues

Hans Driever, Richard Smokers, Ruben Sharpe (TNO)

Stakeholder meeting

September 23, 2009 - European Commission

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Why regulation

	Impacts						
	Reduced car-ownership	More f fuel efficient vehicles	Shift to low-carbon energy carriers	Fuel efficient driving/sailing/flying	Reduced vehicle-kms due to higher vehicle utilisation	Modal shift to low-carbon modes	Limiting overall transport growth
Instrument							
Vehicle CO2 emission regulation							?
Component efficiency regulation							?
Regulation of energy carriers							

- Regulation forces development and marketing of more fuel efficient vehicles
- Depending on definition also shift to low-carbon energy carriers can be promoted

- Regulation has proven to be effective
  - See Euro-standards for exhaust emissions

Why regulation

- Possible indirect and rebound effects
  - Indirect: Higher purchase costs may lead to lower car ownership
  - Rebound: If future fuel efficient vehicles are less expensive to drive this may lead to more kms driven

- Possible co-benefits
  - Reduced dependence on imported oil
  - Strengthening innovative power and international competitiveness of EU industry
  - Air quality & noise
    - Efficient cars are not necessarily clean shift to electricity of hydrogen will also reduce pollutant and noise emissions
  - Improved safety
    - E.g. when using Intelligent Speed Adaptation (ISA)

Options for future regulatory instruments

- Further tightening of CO_2 targets under present / upcoming legislation
- Regulation for HD road vehicles and other modes
- Regulating vehicle energy consumption
  - combined with regulation of well-to-wheel emissions (g/MJ) of energy carriers
- Non-linear utility-based limit functions penalising high emitters
- Vehicle-based limits
- Bin-based systems
  - requiring shares of vehicles meeting different standards
- Regulating energy efficiency of components
- Regulating vehicle parameters
  - power, power-to-weight, size, mass
- Regulating vehicle performance
  - top speed, acceleration
- Mandatory application of externally controlled limitation of speed or acceleration
  - e.g. dependent on road type or location

Criteria for design future regulatory instruments

- Generic vs technology specific
- Appropriate target levels / limit values and target years
- Measurability
- Proportionality between regulated variable and real-world impact
- Accountability
- Fairness
- Possible market distortions
- Loopholes and perverse incentives
- Trade-offs with other regulations
- Rebound effects
- Appropriate level of penalties for non-compliance
- Relation with other GHG policy instruments in same sector

Relation with other policy instruments

- Regulation to be established at EU level rather than Member State level
  - Uniform standards
    - Avoid trade barriers and reduce development costs
  - Competitiveness and innovation in EU industry

- Regulation may interact with other policy instruments at EU and national level
  - Economic / fiscal instruments
  - Labelling
  - Voluntary agreements with sector

Relation with other policy instruments

- Regulation and economic instruments
  - Fuel tax, CO_2-taxation, cap & trade system, etc.
  - Alternatives or complementary measures?
  - Economists favour economic instruments over regulation
    - Generally deliver more cost effective solutions in ideal market
- Reasons for favouring regulation:
  - Fiscal policy difficult to establish in EU
  - Cap & trade system conceivable but difficult to establish for transport
    - Which principal actors?
  - Standards fit in existing EU policy frameworks
  - Regulation can overcome market imperfections:
    - Split incentive: manufacturer has to invest / take risk while user profits from lower fuel costs
    - Consumer myopia
    - Company car taxation
    - Etcetera

Relation with other policy instruments

- Regulation can be useful in combination with economic instruments
  - To make sure that options are available that enable actors to respond to economic instruments
- Other policy instruments may help manufacturers to reach regulatory target
  - Tax incentives, CO_2 differentiation of tax / road pricing, subsidies, labelling, awareness campaigns
  - Some at EU level but mainly at Member State level
- Regulation requires appropriate test procedures which are also relevant for labelling and CO_2 differentiation of tax / road pricing

General issues for future regulation – Technical issues

- Definition of test procedures and test cycles
  - Relation between type approval and real-world impacts
    - representative cycle
    - mileage weighting

- Dealing with alternative propulsion systems and alternative energy carriers
  - May require a new metric (see further on)

General issues for future regulation – Test procedures & test cycles

- Emissions on TA test cycle should correlate with real-world emissions
  - The tighter the limits the more important this gets
  - Proper ranking of vehicles for labelling and CO_2 differentiation of taxes
  - Accurate consumer information
  - May require set of cycles for different driving conditions
- Test procedures must be able to deal with alternative propulsion systems and energy carriers
  - Should be ready in time!
- Test procedures should cover all reduction options that have meaningful impact on real-world CO_2 emissions
  - “eco-innovations” and options covered under Integrated Approach

General issues for future regulation - Factoring in alternative energy carriers

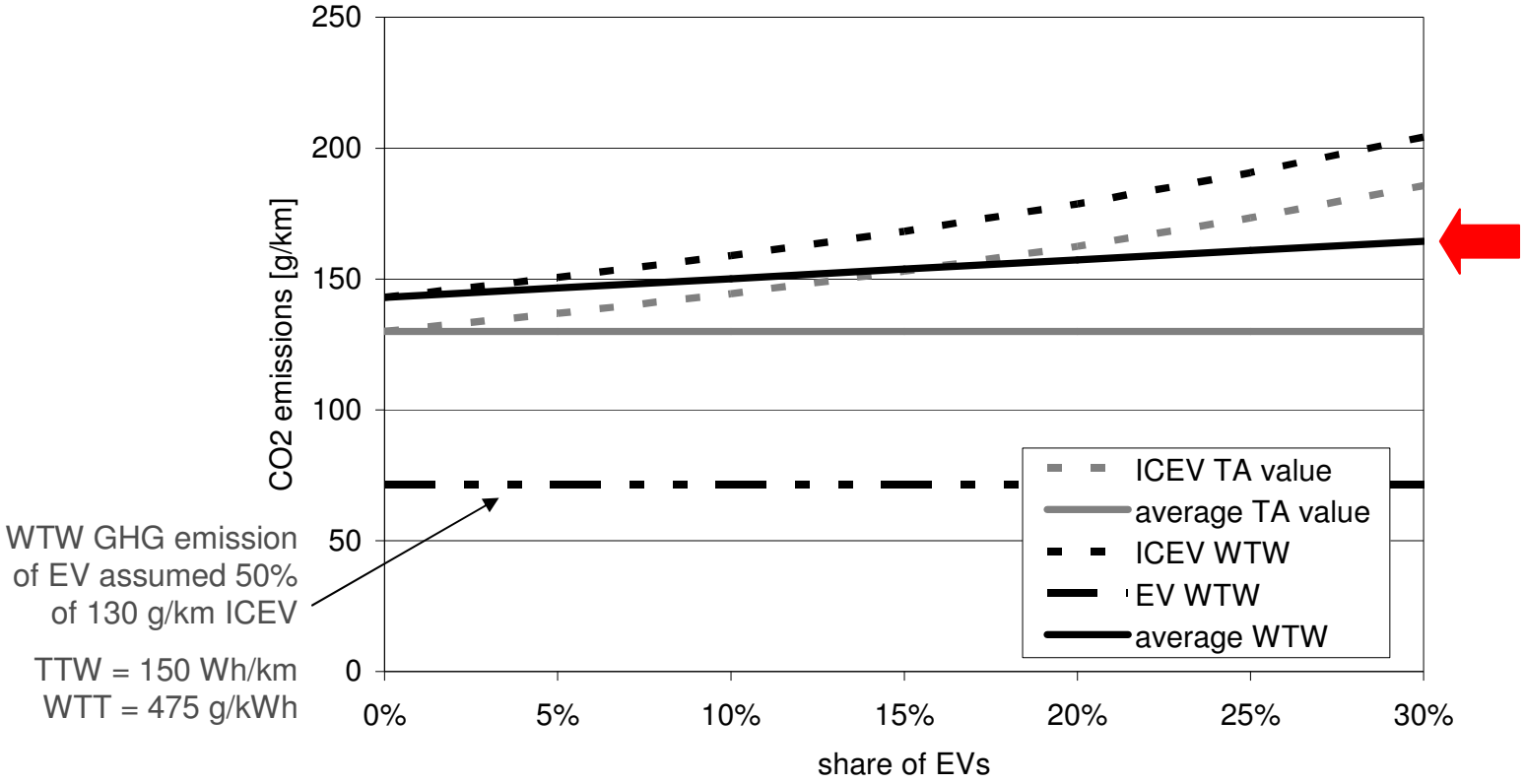
- Alternative energy carriers
  - Biofuels, electricity, hydrogen, electrochemical energy carriers (replacement of entire battery , or active materials as in the case of zinc-air batteries), compressed air, what else?
  - Emissions shift from tank-to-wheel (TTW) to well-to-tank (WTT)
  - Overall well-to-wheel (WTW) emissions must go down

- Alternative metrics
  - TTW CO_2 (g/km)
    - improvement of current system?
  - TTW energy consumption (MJ/km)
  - WTW GHG emissions (g/km) based on TTW energy consumption (MJ/km) and default WTW factors (g/MJ) for energy carriers
  - TTW energy consumptions + separate WTW targets for energy carriers (g/MJ)

- Current CO_2 regulation over-stimulates cars with zero TTW emissions on TA test
  - EVs and FCEVs + electric driving part of plug-in HEVs

General issues for future regulation - Factoring in alternative energy carriers

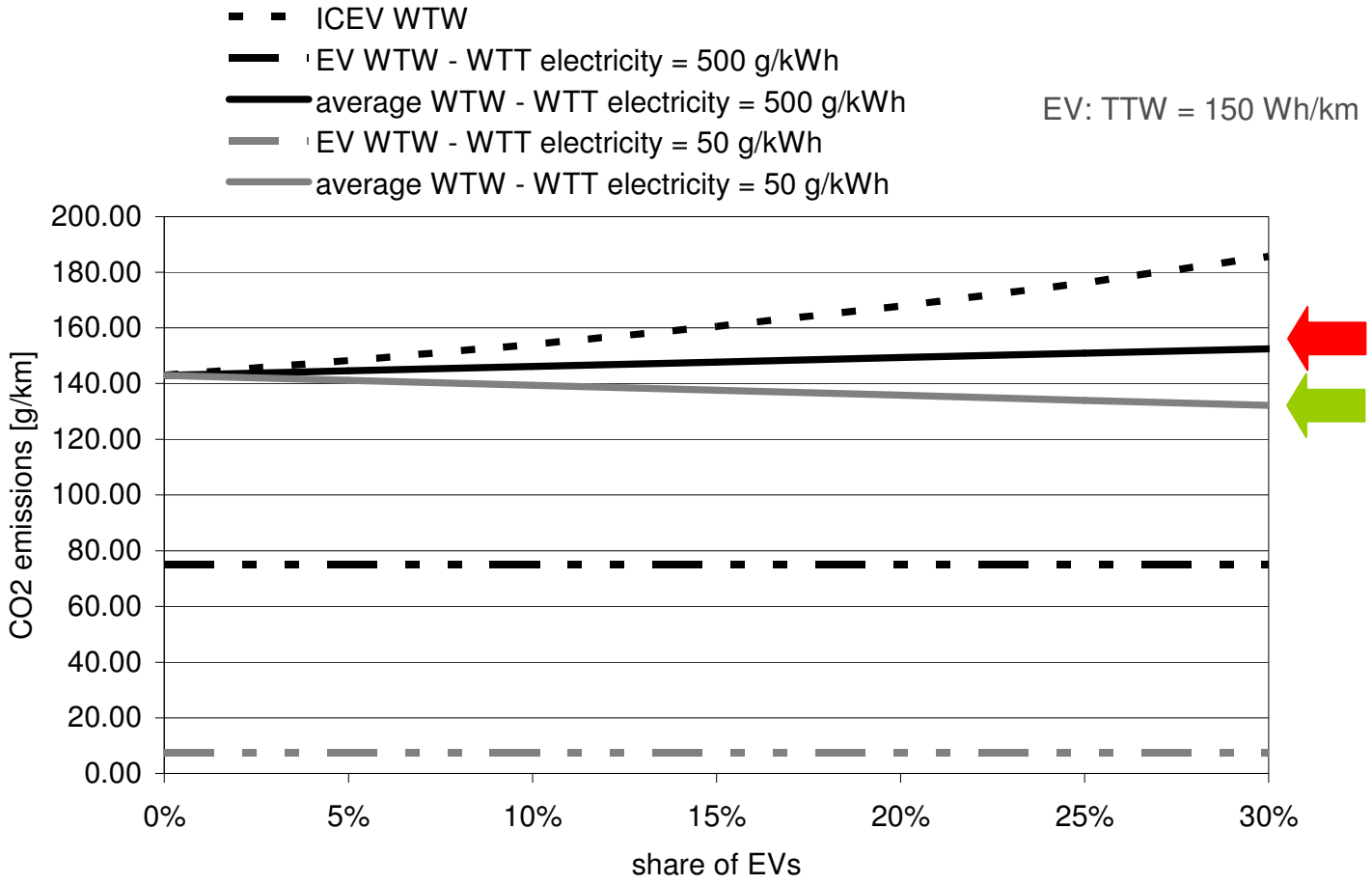
- TTW CO_2 target: Increasing share of EVs always leads to higher WTW emissions unless WTT emissions are zero



Effect of increasing the share of EVs in new vehicle sales on overall CO_2 emissions from passenger cars in case of a 130 gCO_2/km target

General issues for future regulation - Factoring in alternative energy carriers

- TTW energy consumption target: Increasing share of EVs leads to lower WTW emissions if WTT emissions < 290 g/kWh (EU average = 440 g/kWh)



Effect of increasing the share of EVs on overall WTW CO_2 emissions in case of a 1.78 MJ/km TTW efficiency target (equivalent to 130 gCO_2/km for vehicles on petrol/diesel)

General issues for future regulation - Factoring in alternative energy carriers

- Option: Technology neutral WTW target by combining TTW efficiency target for vehicles with default WTT GHG emission values

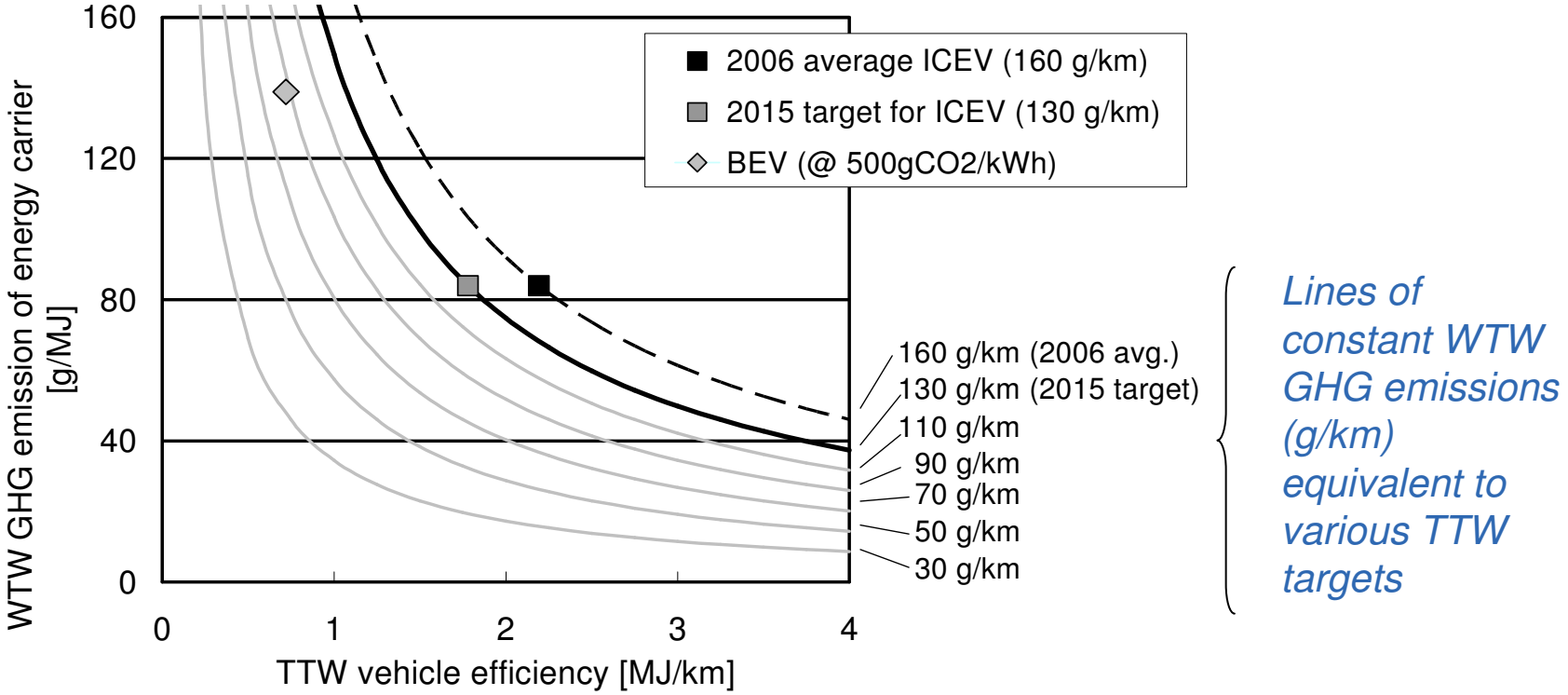


Illustration of how various levels of future targets can be obtained with different combinations of TTW vehicle efficiency improvement and changes in the WTW GHG emission of the energy carrier used

General issues for future regulation - Factoring in alternative energy carriers

- Issues:
  - WTT emissions of large-scale electricity & hydrogen production plants covered by ETS
    - Theoretically: marginal emissions of extra production = zero
    - But in long term increased use of EVs may lead to less stringent ETS cap
  - WTT emissions often occur outside EU
    - Especially biofuels
    - Not covered by ETS
    - Not covered by national GHG emission targets (Kyoto methodology)
  - How to measure (progress wrt) WTT emissions?
  - How to label origin of energy carriers?

  - Fuel Quality Directive (2009/30) contains first attempt at regulating WTT emissions
    - 10% reduction of “life-cycle GHG emissions” (= WTW) by 2020

General issues for future regulation - Factoring in alternative energy carriers

- Theoretical preference for technology neutral WTW standards
- But for practical reasons setting separate targets for different energy carriers should be considered
  - balancing needed to create level playing field
  - could be combined with bin-based system
- Strong coupling required between developments in vehicle regulation and in regulation of energy carriers
  - connected to co-evolution of energy system and mobility system

General issues for future regulation – Including other GHG emissions

- CH_4
  - Euro 5/6: 100 mg/km THC limit = max. 2.5 gCO_2-equiv./km if CH_4
  - Euro VI: 500 mg/kWh CH_4 limit = 1.25 gCO_2-equiv./kWh
- N_2O
  - LD: observed values 1.5 – 20 gCO_2-equiv./km
  - HD: observed values 3 (Euro I – III) to 12 (Euro IV –V) gCO_2-equiv./km
- Black carbon
  - most important climate forcing agent after CO_2 and CH_4
  - requires further study to determine impact from transport
    - can be targeted through exhaust emission standards
- H_2O and other emissions + contrail formation of aircraft at high altitude
  - increases total radiative forcing by factor 2 – 4 times the direct impact of CO_2 emissions

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Regulation for vehicles and energy carriers

Part II – Road vehicles / LD

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Overview of existing regulation and current developments for road vehicles in EU

- Regulation 443/2009 - CO_2 emissions from passenger cars
  - 130 g/km in 2015
    - mass-based limit function with 60% slope applied to set separate target per manufacturer
  - eco-innovations may contribute up to 7 g/km (until test amendment of TA test procedures)
  - 95 g/km in 2020, modalities to be defined by 2013
- Light commercial vehicles
  - in preparation
  - similar system as for passenger cars
- Heavy duty vehicles
  - some initial studies carried out
  - preparatory work being started

Overview of existing regulation and current developments for road vehicles in EU

- Other aspects
  - legislation on tyre pressure monitoring systems (TPMS, COM(2008) 316), gear shift indicators (GSI) and mobile air conditioners (MACs) in preparation
  - labelling of tyres (COM(2009) 348)
  - work on development of new test cycle has started
    - UN ECE WLTP
    - EU may choose to define own cycle if process in UN ECE is unsatisfactory

- Discussion at this stakeholder meeting to focus on longer term issues:
  - post 2020 regulation for LD vehicles
  - regulation for HD vehicles

Overview of existing regulation and current developments outside EU

- Japan: Top Runner Approach
  - Targets based on % reduction compared to best in class in given reference year
  - For HD vehicles fuel economy is determined by combination of testing (engine map) and modelling (vehicle energy requirements)
    - Could be inspiration for HD regulation in EU

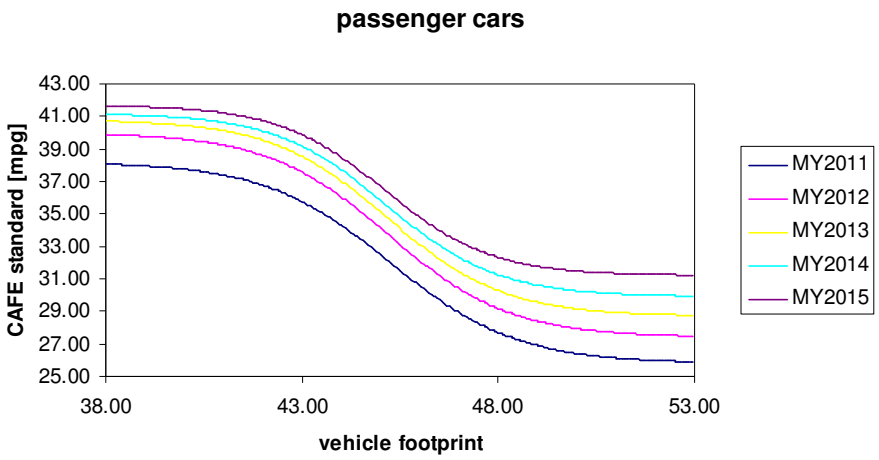
Current efficiency targets for vehicles in the Top Runner program

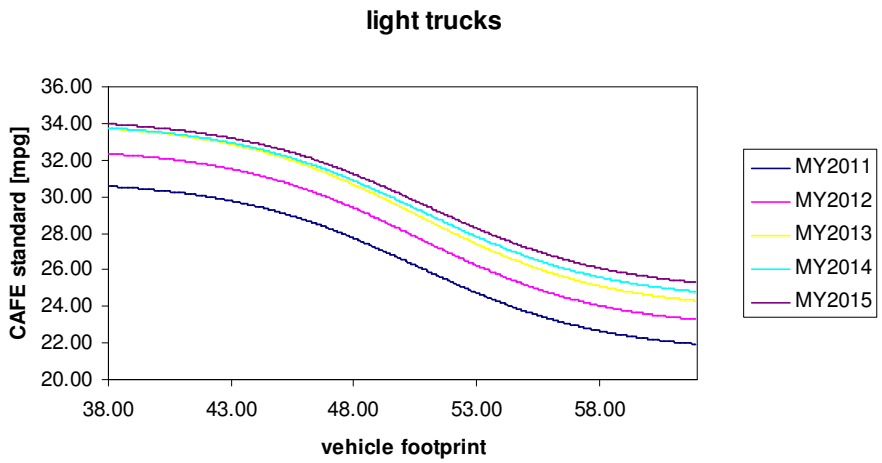
Vehicle type	Reference year	Target year	Target efficiency improvement [%]
Petrol passenger	2004	2015	23.5
Diesel passenger	2004	2015	23.5
LPG passenger	2001	2010	11.4
Vans	2004	2015	7.2
Buses	2002	2015	12.1
Petrol HGV	2004	2015	12.6
Diesel HGV	2004	2015	12.6
Tractors	2002	2015	12.2

Overview of existing regulation and current developments outside EU

20 mpg ≈ 278 gCO_2/km
30 mpg ≈ 185 gCO_2/km
40 mpg ≈ 139 gCO_2/km

- US: update of CAFE
  - new Model Year 2011 target: 27.3 mpg (204 g/km)
  - existing Model Year 2020 target: 35 mpg (159 g/km)
  - new Model Year 2016 target in preparation: 250 gCO_2/mi (155 g/km = 35.8 mpg)
  - proposal for targets based fleet averaging of per vehicle targets based on non-linear function of footprint (wheel base x track width)





Overview of existing regulation and current developments outside EU

200 gCO_2/mile ≈ 124 gCO_2/km
300 gCO_2/mile ≈ 186 gCO_2/km
400 gCO_2/mile ≈ 249 gCO_2/km

- California: CARB
  - own set of CO_2 emission standards
  - stricter than federal standards
    - 2015 target for pass. car = 132 g/km: equivalent to EU target

Tier	Year	CO2-equivalent emission standard (g/mi)	
		PC/LDT1 (Passenger cars and small trucks/SUVs)	LDT2 (Large trucks/SUVs)
Near-term	2009	323	439
	2010	301	420
	2011	267	390
	2012	233	361
Mid-term	2013	227	355
	2014	222	350
	2015	213	341
	2016	205	332

Issues for future regulation of CO_2 emissions from passenger cars and vans

- Mid-term (2015-30)
  - Modalities for implementing 95 g/km
  - Choice of utility parameter
    - Footprint (track width x wheel base) is important candidate
    - Closer correlation with functionality of vehicle?
      - # of seats, trunk space
  - Targets for period beyond 2020
    - What is necessary?
    - What is feasible? Depends on:
      - further reduction potential of conventional vehicles and
      - rate at which alternative powertrains and renewable energy carriers can be introduced in transport sector
    - 50 gCO_2-equiv./km WTW in 2030 ??
      - roughly factor 2 compared to 2020 target

Issues for future regulation of CO_2 emissions from passenger cars and vans

- Mid-term (2015-30)
  - Improved test procedure
    - Correlation with real-world driving
  - Mileage weighting?
    - To improve correlation between reduction of fleet average gCO_2/km and real-world net GHG emission reduction in Mton/year
  - Dealing with alternative energy carriers
    - may require alternative metric and connection to standards for fuels / energy carriers
    - see Part I
  - Regulation for components?
    - Tyres, TPMS, mobile air conditioners
    - Eco-innovations
    - Auxiliaries (e.g. systems for power steering of brake assistance)
    - In car systems

Aspects for defining regulation
(based on IEEP/CE/TNO 2007)

- Obligated or responsible legal entity:
  - Options: trade associations; manufacturers or manufacturer groups; importers, distributors and dealers; and Member States
- Target focus
  - Options for level of obligation: e.g. at Member State or EU level
  - Options for nature of obligation: e.g. model/variant or group average target
- Target type:
  - Options: single target (s), sloped line or other utility-based targets, other options
  - Single target(s) also include systems based on "bins" where different minimum shares of the fleet / sales have to meet different levels of fixed targets.
- Instrument/sanction:
  - Exclusion of non-compliant models / manufacturers from the market
  - Fines or feebates (fines + rebates)
    - Fine should exceed costs for meeting the target
  - Possibly combined with various options of trading (among manufacturers or with ETS credits, but note principal-agent problems, see slide 3)
- Choice of a utility function (in case of sloped line or other utility-based targets):
  - Options for utility parameters: vehicle mass, pan area (vehicle l x w), and footprint (track width x wheel base), but other options (incl. combined parameters) are conceivable
  - Options for type of utility-based limit function: e.g. linear, linear with flat shoulders for small and/or large cars, non-linear functions

Considerations on utility parameter

- Good measure of 'utility'
  - I.e. encourage acceptable aspects of utility rather than controversial or less acceptable ones
- Correlation with CO_2 emissions
  - Some correlation necessary to serve as basis for differentiating targets
  - Correlation should not be too good
    - Spread shows room for CO_2 reduction by other means than reducing value of utility parameter
    - Good correlation means parameter is determinant, but reduction of utility value translates into lower target and is thus not awarded
- Preference for a continuously-variable function
- Availability of required data
  - Actually available or easily obtainable
- Understandable
  - Stakeholders tend to have preference against a complex function or variable
  - Ease of communication is obviously important / useful
  - But not a valid argument against complex function / variable if this is necessary to correctly represent reality and distribute the burden according to sensible criteria

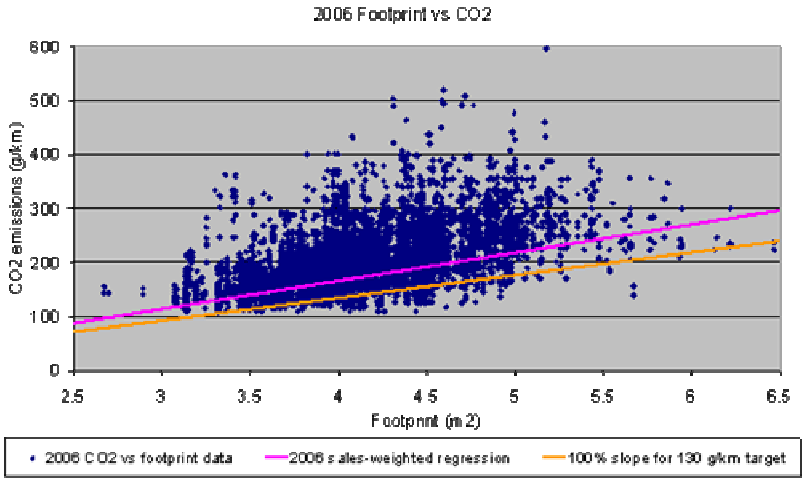
Considerations on utility parameter

- Perverse effects (i.e. incentive to ‘gaming’) should be minimised
  - Increasing value of utility parameter should not reduce effort for compliance
- Adverse effects (e.g. reduced vehicle safety) should be avoided
- Should not exclude specific technical options
- Distributional impacts:
  - For current legislation a criterion has been that it should not unfairly disadvantage any particular manufacturer group on account of characteristics of their model portfolio
  - For longer term definition of “fair” distribution needs to be re-evaluated in light of urgency and required stringency of future targets

Considerations on utility parameter - Footprint

- Possible benefits of using footprint rather than weight as a utility parameter:
  - Good measure of the 'space' available in the vehicle cabin;
  - Appears to limit possibilities of manipulation or 'gaming' of vehicle characteristics to increase the CO_2 allowance for a particular vehicle
  - Fully rewards and does not penalise efforts towards weight reduction
  - US evidence suggests that footprint is associated with improved safety, whereas weight *per se* is associated with an increase in fatalities

- Footprint will be considered as candidate for 95 g/km target, but other options not excluded
- Monitoring Mechanism will be adapted to collect footprint data



Issues for future regulation of CO_2 emissions from passenger cars and vans

- Long-term (2030-50)
  - Future target levels in relation to overall long-term > 80% GHG emission reduction requirement for stabilising climate change
  - Focus on WTW GHG emissions
    - Create level playing field for long-term sustainable solutions
  - Choice of utility parameter
  - Regulating vehicle parameters?
    - power, power-to-weight, size, mass
  - Regulating vehicle performance?
    - top speed, acceleration
  - Mandatory application of technologies?
    - In combination with standards for components

Issues for future regulation of CO_2 emissions from passenger cars and vans

- Long-term (2030-50)
  - Mandatory application of externally controlled limitation of speed or acceleration?
  - Regulating / monitoring real world impacts
    - Requires data
    - IT and communication infrastructures now being developed and built up may enable future data collection and real-time monitoring of fuel consumption and drive characteristics
      - navigation and communication systems
      - vehicle-to-vehicle and vehicle-to-road communications
    - ITS
      - collision avoidance opens huge perspective for further efficiency improvement

Conclusions wrt CO_2 regulation for cars and vans

- Regulation remains useful instrument in longer term
  - Also in combination with more generic economic instruments
- Long-term regulation must create level playing field for all sustainable technologies (vehicles + energy carriers)
  - From TTW to WTW
  - Design of generic system is not straightforward
- Appropriate test procedures necessary
  - Representative cycle(s)
  - Able to assess impact of all technologies that reduce real-world GHG emissions
- Medium and long-term targets may require different utility parameter
  - footprint
  - better measures of functional utility?
- Additional regulations may be necessary to reach long-term targets
  - vehicle attributes / performance
  - mandatory application of technologies

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Regulation for vehicles and energy carriers

Part III – Road vehicles / HD

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Status of regulation for HD vehicles

- Some initial studies carried out
- EU intends to design HD vehicle regulation in coming years
  - preparatory work being started

- Challenges for designing HD vehicle regulation:
  - TA emission test is engine-based
  - Whole vehicle TA test requires HD chassis dynamometer
  - Large variety of final vehicle configurations
  - Large number of multi-stage vehicles
    - Chassis-cab combinations produced by OEM
    - Fitted with build-up by “final stage” manufacturers (often MSE)
  - Reduction potential from engine improvements is limited
    - Small contributions from a lot of different measures possible

HD vehicles
Technical options

- Making the engine and drive-train more efficient by:
  - optimisation of the engine efficiency by, amongst others, down-scaling and exhaust energy recovery
  - improvement of the transmission such as an optimised automatic gearbox
  - hybrid elements such as idle shut-down (avoiding idling of the engine), break energy recovery systems, and acceleration assistance

- Reducing the need for mechanical (drive) energy by:
  - mass reduction
  - reduction of tractive resistance
  - reduction of rolling resistance
  - reduction of air resistance

HD vehicles
Options for test methods

#	Option	Advantage	Disadvantage
1	Engine test bench	– Matches with present emission tests – Moderate costs	– Not representative for all aspects that determine the CO_2 emission of vehicle – Not suitable for hybrid vehicles
2	Vehicle model + engine test bench (*Top Runner* type approach)	– Moderate costs if the model can be kept simple – Fairly representative if the model is OK	– Usefulness depends on availability of correct parameters – Complex in case of hybrid powertrain – Transient behaviour of engine is tested to some extent only – Confidentiality of data
3	a) Transient chassis dynamometer b) power train test bench	– Representative – Suitable for hybrids	– High costs – Limited capacity in Europe – Air drag must be determined separately
4	Measurements on test track	– Representative – Matches the present research with PEMS – Suitable for hybrids	– High costs – Irreproducibility of test conditions
5	Measurements on road / field test	– Representative – Suitable for hybrids	– Irreproducibility of test conditions and driving pattern – Need for a fixed trajectory

HD vehicles
Options for test methods

	reproducibility	representation	availability	costs
Engine test bench	++	-	+	++[1]
Vehicle model + engine test bench	++	+ / 0	+	+ / 0
Dynamometer / power train test bench	+	++ / +	-[2]	+ / 0
Test track	0	++	+	+
Measurement on road / field test	-	++	+	+ / 0

[1] In case engine test can be done directly following the present emission measurements
[2] Capacity in Europe is limited at this time

HD vehicles
Options for test methods

- The model for option 2 incorporates the following parameters:
  - Vehicle weight
  - Air drag of the vehicle
  - Rolling resistance of the tyres
  - Gearing ratios of the gear box
  - Friction losses and inertia in the drive train
  - Losses in auxiliary aggregates such as the generator, compressor and steering pump
  - Engine maps for CO_2 emission and fuel consumption
- Powertrain test bench (option 3) is hardware-in-the-loop
  - Also requires vehicle parameters for setting resistance factors
- Options 2, 3 and 4 are considered most viable

HD vehicles
Options for regulatory instruments

- Some possible alternatives:
  - Engine efficiency standard
    - applied per engine or on the sales average per manufacturer
  - Powertrain efficiency standard
    - based on measurements on a powertrain test bed with simulated load for one or more vehicle configurations, applied per powertrain or on the sales average per manufacturer
  - Whole vehicle CO_2 emission standard
    - based on simulating engines / power trains in default vehicle configurations, applied per engine / powertrain or on the sales average per manufacturer, OR
    - based on whole vehicle testing on a dynamometer or test track for a limited number of standardised vehicle configurations, applied per vehicle model / type or on the sales average per manufacturer
- Standards applied per engine, powertrain or vehicle may be differentiated according to class of application
- Payload might be used as utility parameter
- Regulating components:
  - E.g. cooled transport: energy efficiency regulation of cooling equipment
  - Superstructures

HD vehicles
Options for regulatory instruments

- Instead of g/km standard also g/tonkm can be considered
  - e.g. using default values for average load as function of max. payload
- To fully capture possible improvements wrt vehicle mass, aerodynamics and rolling resistance also separate regulations for vehicle build-ups, trailers or components could be useful, e.g.;
  - air drag of trailers
  - air drag of cabins
  - energy consumption of auxiliaries
  - payload to weight ratio of vehicle build-up and trailers
  - payload to weight ratio of whole vehicle
- Removing regulatory obstacles important for effective regulation of vehicles, vehicle build-ups, trailers or components
  - current weights/dimensions legislation limits total length of the vehicle thus preventing aerodynamic elements in front and rear
  - rear view mirrors may be replaced by cameras (also cars)

Issues for future regulation of CO_2 emissions from HD vehicles

- Mid-term
  - Establishing “version 1.0” of HD CO_2 regulation
  - Appropriate test procedure
  - Appropriate regulation for vehicle build-ups, trailers or components
  - Monitoring effectiveness

- Long-term
  - Issues for long term same as with LD vehicles
  - Future target levels in relation to overall long-term > 80% GHG emission reduction requirement for stabilising climate change
  - Representative test procedures and cycle
  - Suitable metric for dealing with alternative energy carriers
    - From TTW to WTW
    - Create level playing field for long-term sustainable solutions
  - Mandatory application of technologies?
    - In combination with standards for components

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Any questions??

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