Association ASPEN

AEA Energy & Environment
From the AEA group

# Assessment of options for the legislation of $CO_2$ emissions from light commercial vehicles

CE Delft

TNO

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

ENV.C.5/FRA/2006/0071

# LCVs & $CO_2$ | Contents

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- definition of utility-based limit functions
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# LCVs & $CO_2$ | Project team

- CE Delft: *Richard Smokers, Gerdien van de Vreede, Femke Brouwer*
- TNO: *Gerben Passier*
- AEA: *Ian Skinner*

- work is part of larger project “Impacts of regulatory options to reduce $CO_2$ emissions from cars, in particular on car manufacturers”, carried out by a consortium led by AEA with CE, TNO and Öko-Institut as partners

# LCVs & $CO_2$ | Project context

- part of European Commission's plans as outlined in COM(2007) 19 and SEC(2007) 60
  - $CO_2$ legislation for LCVs as element in Integrated Approach to bridge 10 g/km gap between overall goal of 120 g/km and the M1 target of 130 g/km
  - objective of reaching 175 g/km $CO_2$ by 2012 and 160g/km $CO_2$ by 2015
- approach preferably similar to legislation for M1
- European Commission has requested assessment of following options:

| target [g/km] | target year | target types | slope values | AMI assumptions |
|---|---|---|---|---|
| 175 | 2012 | utility-based limit function for mass and pan area percentage reduction | 0 – 140%<br>n.a. | 0.0 – 1.5% p.a.<br>0.0 – 1.5% p.a. |
| 175 | 2015 | utility-based limit function for mass and pan area percentage reduction | 0 – 140%<br>n.a. | 0.0 – 1.5% p.a.<br>0.0 – 1.5% p.a. |
| 160 | 2015 | utility-based limit function for mass and pan area percentage reduction | 0 – 140%<br>n.a. | 0.0 – 1.5% p.a.<br>0.0 – 1.5% p.a. |

# LCVs & $CO_2$ | Project history

- **IEEP/CE/TNO 2007:** *Service Contract on possible regulatory approaches to reducing $CO_2$ emissions from cars,* DG Environment, contract nr. 070402/2006/452236/MAR/C3
- **TNO/IEEP/LAT 2006:** *Service Contract to review and analyse the reduction potential and costs of technological and other measures to reduce $CO_2$ emissions from passenger cars*, DG Enterprise, contract nr. SI2.408212
- **IEEP/TNO/CAIR 2004:** *Service Contract on a business impact assessment of measures to reduce $CO_2$ emissions from passenger cars*, DG Environment, contract nr. B4-3040/2003/366487/MAR/C2
- **TNO/IEEP/LAT 2004:** *Service Contract on the policies for reducing $CO_2$ emissions from light commercial vehicles*, DG Environment, B4-3040/2003/364181/MAR/C1.
- **IEEP/TNO/CAIR 2003:** *Service Contract on the future of the passenger car $CO_2$ strategy, DG-Environment*

- TNO cost assessment model has been developed, used and updated in above projects

# LCVs & $CO_2$ | Definitions

- N1 vehicles are motor vehicles with at least four wheels designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes
- Classes of N1 vehicles on the basis of reference mass:
  - Class I: reference mass ≤ 1305kg
  - Class II: 1305 kg < reference mass ≤ 1760 kg
  - Class III: reference mass > 1760 kg

- Regulation is intended to cover N1, N2 and M2 vehicles with reference mass not exceeding 2610 kg.
  - further extended to vehicles with reference mass up to 2840 kg of which other model variants are type approved as N1, N2 or M2 with reference mass below 2610 kg
  - harmonisation with scope of Euro 5/6 legislation

# LCVs & $CO_2$ | Definitions

- Sales database contains kerb weight instead of reference mass
  - kerb weight is total weight of vehicle with standard equipment, all necessary operating consumables (such as motor oil and coolant), a full tank of fuel, and not loaded with either passengers or cargo.
  - definition of kerb weight not consistent
    - incl. or excl. 75 kg for driver?
  - approximate definitions used
    - reference mass = kerb weight + 60 kg
- Relation between additional manufacturer costs and additional retail price based on ACEA tax guide data

# LCVs & $CO_2$ | Database for LCVs

JATO has supplied two datasets:

- 2007 “Vols database”
  - vehicle registration data and limited technical information (but containing $CO_2$ combined, kerb weight, payload, overall length, overall width, overall height, wheelbase, cargo volume, sales) for 20 European countries in 2007
- 2007 “Specs database”
  - extensive technical data for all vehicles registered in 20 countries in 2007 but no sales data (included in addition to the Vols database: base price, $CO_2$ and fuel consumption for urban, extra-urban and combined, front and rear track width, and cargo space dimensions).
  - For 9 countries JATO has established a coupling between the Vols and the Specs database so that for these countries the Specs database also contains sales volumes

# LCVs & $CO_2$ | Database for LCVs

- Filtering applied
  - all typical passenger cars (registered as van) removed
  - small vans (Berlingo / Kangoo / Doblo-type) assumed N1
  - large pick-ups assumed N1
  - all other SUVs assumed M1 and removed
  - campers considered M1 and removed
  - minibuses ≤ 9 seats considered M1 and removed
  - midibuses > 9 seats considered M2 and included
  - other fuels than petrol and diesel excluded

- All remaining vehicles labelled class I, II or III based on reference mass
- Missing $CO_2$ data estimated on basis of linear fit through available data on other vehicles in same model range
  - or average if number of available $CO_2$ data was limited
  - or based on fit through data on other vehicles in same class if no $CO_2$ data available for given model

# LCVs & $CO_2$ | Database for LCVs

- Multi-stage vehicles
  - chassis-cab combination fitted with build-up by “final stage manufacturer” after vehicle is sold to customer by OEM
  - can not be identified on basis of information in database
    - largest share expected in class II and class III
  - $CO_2$ emission data will generally be missing for 2007
    - when available, lower $CO_2$ emissions measured without build-up are partly compensated by lower mass
  - share in overall sales only 8%
- Uncertainties with respect to multi-stage vehicles are considered not to prohibit the definition of an appropriate limit function for the $CO_2$ legislation for LCVs

- Available $CO_2$ data in database are considered sufficient for defining correct fit through 2007 data

# LCVs & $CO_2$ | Database for LCVs

- Shares of petrol / diesel
  - Share of different fuels in N- and M-type vehicle sales in the JATO database

| | N | M |
|---|---|---|
| **petrol** | 2.1% | 3.8% |
| **diesel** | 96.7% | 93.1% |
| **CNG** | 0.5% | 0.1% |
| **other** | 0.7% | 3.1% |
| **total** | 100.0% | 100.0% |

  - Share of different fuels and classes in sales of N-type vehicles according to [TNO 2004]

| **TNO 2004** | petrol | | | diesel | | |
|---|---|---|---|---|---|---|
| | I | II | III | I | II | III |
| share of sales per class[1] | 27.5% | 33.0% | 39.5% | 27.5% | 33.0% | 39.5% |
| share of sales per fuel[2] | 34.1% | 34.1% | 34.1% | 65.9% | 65.9% | 65.9% |
| share of sales per fuel per class | 9.4% | 11.3% | 13.5% | 18.1% | 21.7% | 26.0% |

[1]) based on data from Member State registration bodies and RAND 2002

[2]) based on TREMOVE

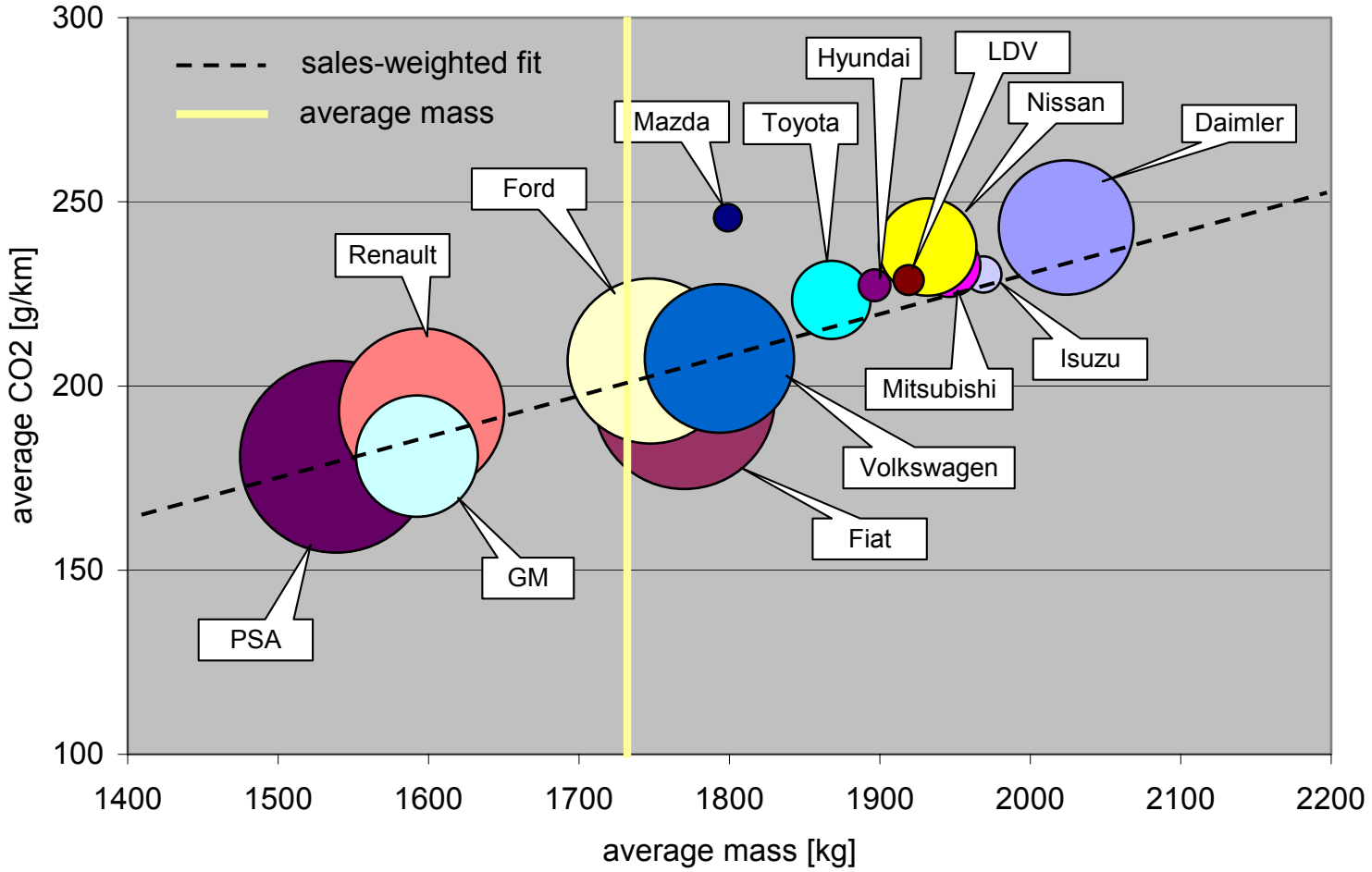
# LCVs & $CO_2$ | Database for LCVs

- 2007 averages and sales data

| manufacturer | 2007-data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CO2 | mass | pan are | sales | | | | | | |
| | [g/km] | [kg] | [m^2] | | | | | | | |
| | avg. | avg. | avg. | p,I | p,II | p,III | d,I | d,II | d,III | total |
| **ACEA** | | | | | | | | | | |
| Daimler | 243 | 2024 | 10.9 | 0 | 35 | 365 | 0 | 4623 | 151677 | 156700 |
| Fiat | 196 | 1770 | 9.9 | 6308 | 532 | 0 | 28401 | 75819 | 168481 | 279541 |
| Ford | 207 | 1748 | 9.7 | 147 | 376 | 962 | 2358 | 116737 | 114927 | 235507 |
| GM | 181 | 1592 | 8.6 | 1428 | 351 | 906 | 30483 | 45157 | 49920 | 128245 |
| PSA | 181 | 1539 | 8.6 | 6830 | 399 | 0 | 131167 | 66020 | 112850 | 317266 |
| Renault | 193 | 1595 | 8.8 | 5164 | 1597 | 278 | 87669 | 28367 | 110797 | 233872 |
| Volkswagen | 207 | 1793 | 9.4 | 747 | 3132 | 1093 | 1882 | 71094 | 112716 | 190664 |
| **JAMA** | | | | | | | | | | |
| Isuzu | 230 | 1969 | 9.2 | 0 | 0 | 0 | 0 | 422 | 11127 | 11549 |
| Mazda | 246 | 1799 | 9.1 | 0 | 0 | 0 | 876 | 622 | 5225 | 6723 |
| Mitsubishi | 233 | 1946 | 9.2 | 0 | 0 | 0 | 460 | 137 | 34078 | 34675 |
| Nissan | 238 | 1932 | 9.6 | 363 | 65 | 119 | 4363 | 12604 | 64649 | 82163 |
| Toyota | 223 | 1868 | 9.3 | 0 | 0 | 0 | 51 | 6680 | 46508 | 53239 |
| **KAMA** | | | | | | | | | | |
| Hyundai | 227 | 1897 | 9.0 | 0 | 96 | 0 | 0 | 1510 | 7448 | 9054 |
| **Other** | | | | | | | | | | |
| LDV | 229 | 1919 | 10.9 | 0 | 0 | 0 | 0 | 13 | 7884 | 7897 |
| **total / average** | 203 | 1731 | 9.4 | 20987 | 6583 | 3723 | 287710 | 429805 | 998287 | 1747095 |
| **share** | | | | 1.2% | 0.4% | 0.2% | 16.5% | 24.6% | 57.1% | |

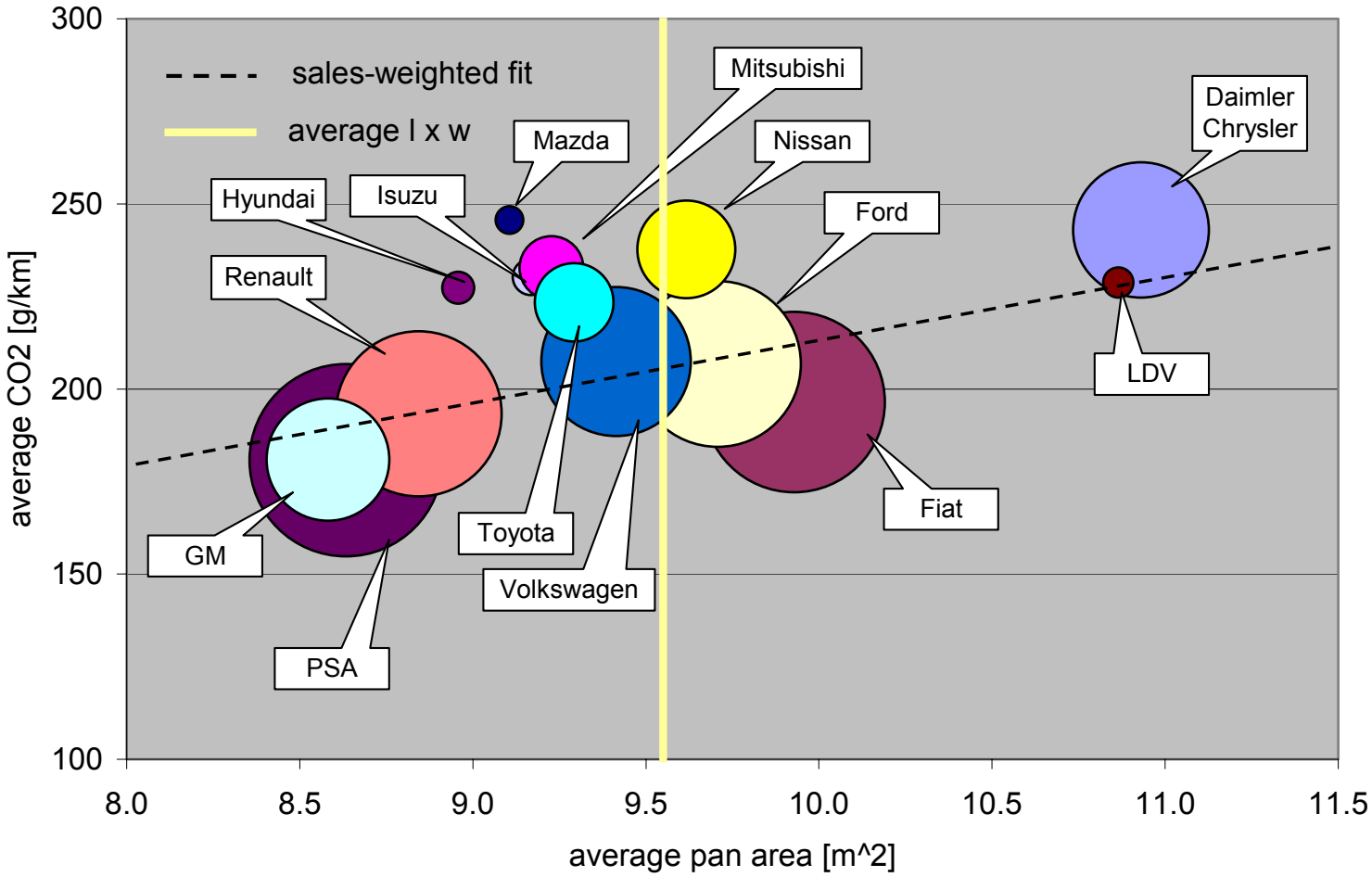
# LCVs & $CO_2$ | Database for LCVs

- average $CO_2$ as function of mass, weights determined by sales



# LCVs & $CO_2$ | Database for LCVs

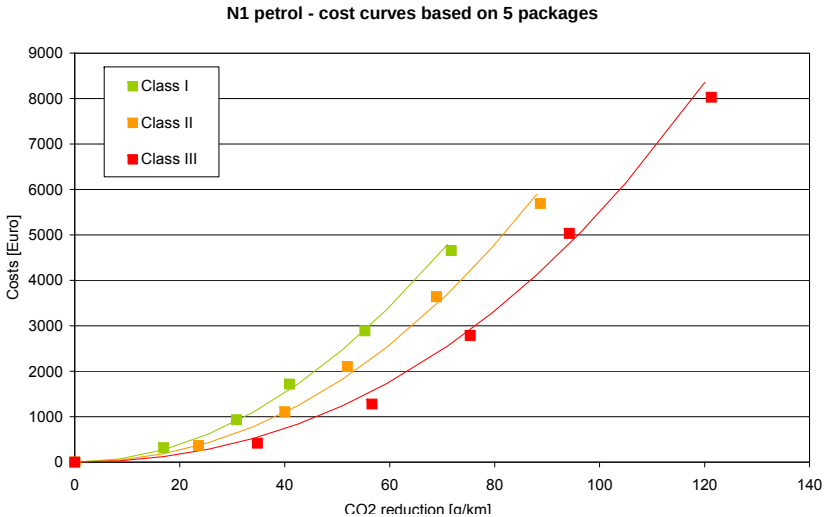
- average $CO_2$ as function of pan area (l x w), weights determined by sales

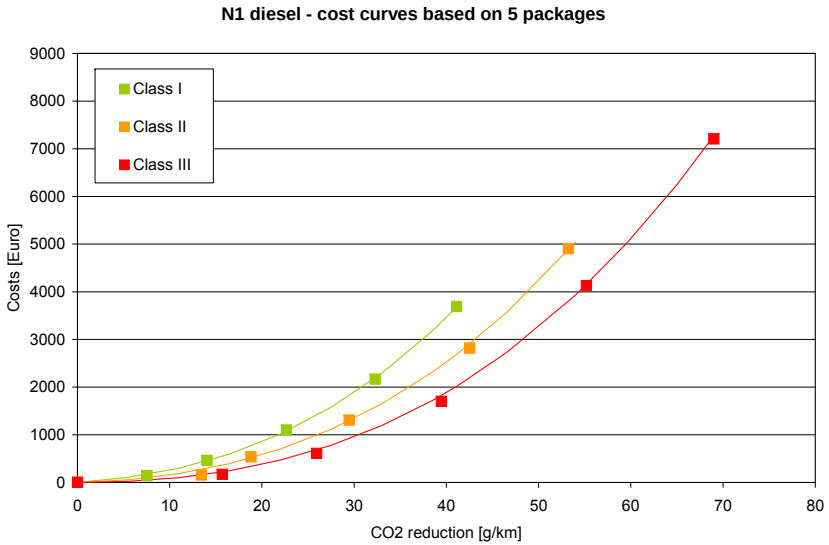


# LCVs & $CO_2$ | Update of cost curves

- based on methodology and cost figures from [TNO 2006]
- $CO_2$ emissions of 2002 reference vehicles updated on basis of 2007 data
  - with assumed efficiency improvement between 2002 and 2007
- cost curves based on $CO_2$ reduction and costs of 5 packages
  - includes indicative correction factor for avoiding double counting of effect from measures that apply to same energy loss

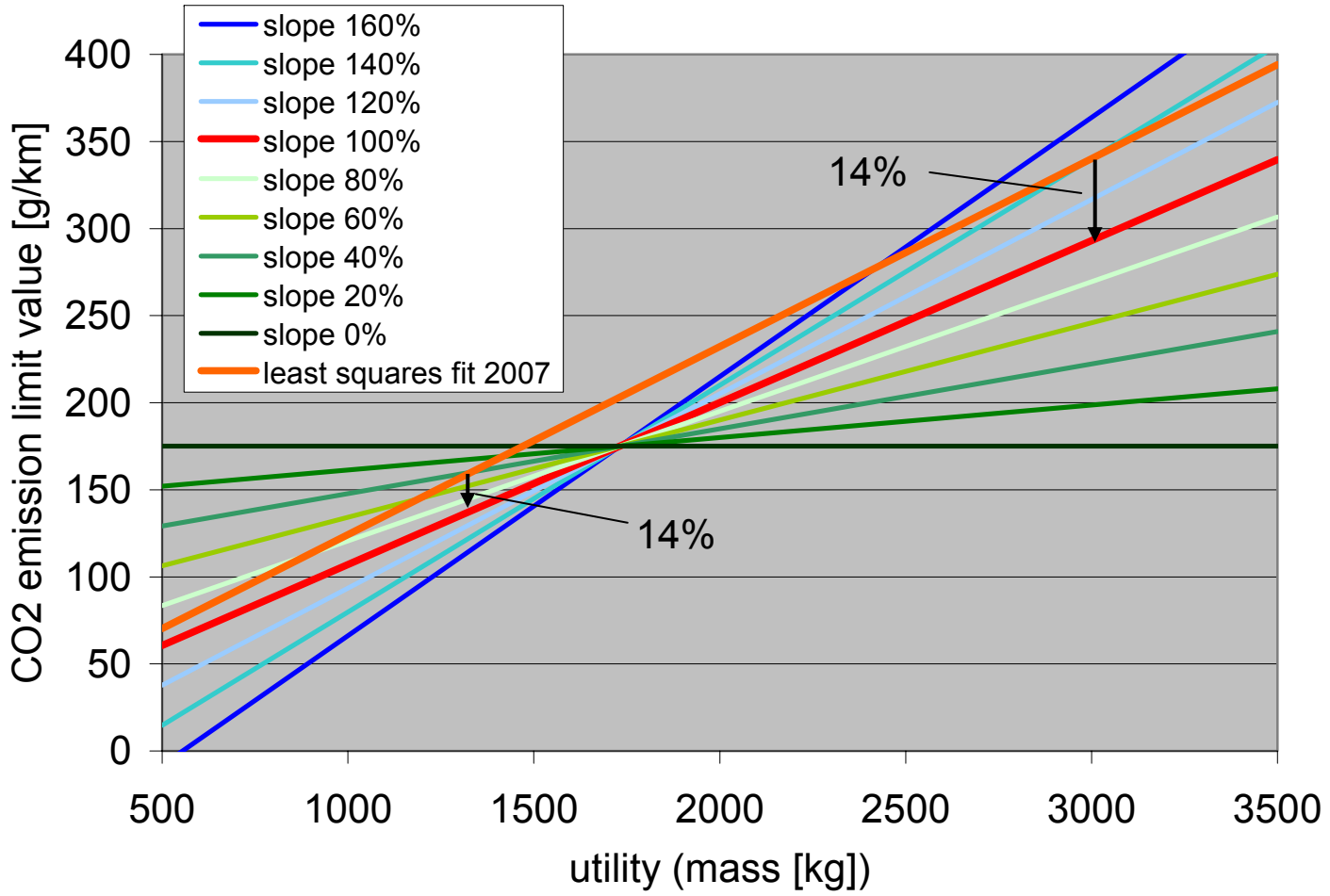
$$CO_2^{combined} = correction\_factor \times CO_2^{baseline} \times \prod_{i=1}^{n}(1-\delta_i)$$



# LCVs & $CO_2$ | Definition of utility-based limit functions

- methodology identical to M1 case



# LCVs & $CO_2$ | Definition of utility-based limit functions

- limit functions developed for:
  - 175 g/km in 2012, with AMI = 0.0%, 0.82% and 1.5% p.a.
  - 175 g/km in 2015, with AMI = 0.0%, 0.82% and 1.5% p.a.
  - 160 g/km in 2015, with AMI = 0.0%, 0.82% and 1.5% p.a.

- examples:

| CO2(reference mass) | | | target year | | 2012 | |
|---|---|---|---|---|---|---|
| AMI | 0.00% | | 0.82% | | 1.50% | |
| target | 175 | | 175 | | 175 | |
| slope | a | b | a | b | a | b |
| 2007 fit | 0.1079 | 16.33 | 0.1079 | 16.33 | 0.1079 | 16.33 |
| 160% | 0.1488 | -82.48 | 0.1433 | -83.31 | 0.1389 | -83.98 |
| 140% | 0.1302 | -50.30 | 0.1254 | -51.02 | 0.1215 | -51.60 |
| 120% | 0.1116 | -18.11 | 0.1075 | -18.73 | 0.1042 | -19.23 |
| 100% | 0.0930 | 14.07 | 0.0895 | 13.55 | 0.0868 | 13.14 |
| 90% | 0.0837 | 30.17 | 0.0806 | 29.70 | 0.0781 | 29.33 |
| 80% | 0.0744 | 46.26 | 0.0716 | 45.84 | 0.0694 | 45.51 |
| 70% | 0.0651 | 62.35 | 0.0627 | 61.99 | 0.0608 | 61.70 |
| 60% | 0.0558 | 78.44 | 0.0537 | 78.13 | 0.0521 | 77.88 |
| 50% | 0.0465 | 94.54 | 0.0448 | 94.28 | 0.0434 | 94.07 |
| 40% | 0.0372 | 110.63 | 0.0358 | 110.42 | 0.0347 | 110.26 |
| 30% | 0.0279 | 126.72 | 0.0269 | 126.57 | 0.0260 | 126.44 |
| 20% | 0.0186 | 142.81 | 0.0179 | 142.71 | 0.0174 | 142.63 |
| 10% | 0.0093 | 158.91 | 0.0090 | 158.86 | 0.0087 | 158.81 |
| 0% | 0.0000 | 175.00 | 0.0000 | 175.00 | 0.0000 | 175.00 |

| CO2(pan area) | | | target year | | NA | |
|---|---|---|---|---|---|---|
| AMI | NA | | NA | | NA | |
| target | 175 | | 175 | | 160 | |
| slope | a | b | a | b | a | b |
| 2007 fit | 17.2792 | 40.20 | 17.2792 | 40.20 | 17.2792 | 40.20 |
| 160% | 23.8848 | -49.44 | 21.8376 | -45.20 | 21.8376 | -45.20 |
| 140% | 20.8992 | -21.38 | 19.1079 | -19.55 | 19.1079 | -19.55 |
| 120% | 17.9136 | 6.67 | 16.3782 | 6.10 | 16.3782 | 6.10 |
| 100% | 14.9280 | 34.73 | 13.6485 | 31.75 | 13.6485 | 31.75 |
| 90% | 13.4352 | 48.76 | 12.2836 | 44.58 | 12.2836 | 44.58 |
| 80% | 11.9424 | 62.78 | 10.9188 | 57.40 | 10.9188 | 57.40 |
| 70% | 10.4496 | 76.81 | 9.5539 | 70.23 | 9.5539 | 70.23 |
| 60% | 8.9568 | 90.84 | 8.1891 | 83.05 | 8.1891 | 83.05 |
| 50% | 7.4640 | 104.86 | 6.8242 | 95.88 | 6.8242 | 95.88 |
| 40% | 5.9712 | 118.89 | 5.4594 | 108.70 | 5.4594 | 108.70 |
| 30% | 4.4784 | 132.92 | 4.0945 | 121.53 | 4.0945 | 121.53 |
| 20% | 2.9856 | 146.95 | 2.7297 | 134.35 | 2.7297 | 134.35 |
| 10% | 1.4928 | 160.97 | 1.3648 | 147.18 | 1.3648 | 147.18 |
| 0% | 0.0000 | 175.00 | 0.0000 | 160.00 | 0.0000 | 160.00 |

# LCVs & $CO_2$ | Results of cost assessment

- cost assessment model based on model for M1s from previous projects
  - divides distribution efforts per manufacturer over vehicle segments based on lowest overall manufacturer costs
    - equal marginal costs per segment
  - improved to take account of maximum reduction potential per segment

- assumptions on autonomous mass increase (AMI)
  - AMI = 0.0% p.a. / 0.82% p.a. / 1.5% p.a. for consistency with M1 assessment
  - AMI = 2.5% considered not likely for N1s
  - sales per class kept constant

- AMI is only time-dependent parameter in model
  - cost curves are static: cost for level of reduction if required to meet target in 2012-2015 period

# LCVs & $CO_2$ | Results of cost assessment

- 175 g/km can be met for mass-based limit with slope ≥ 80%
- 160 g/km can not be met with existing cost curves
  - except for percentage reduction target and low AMI

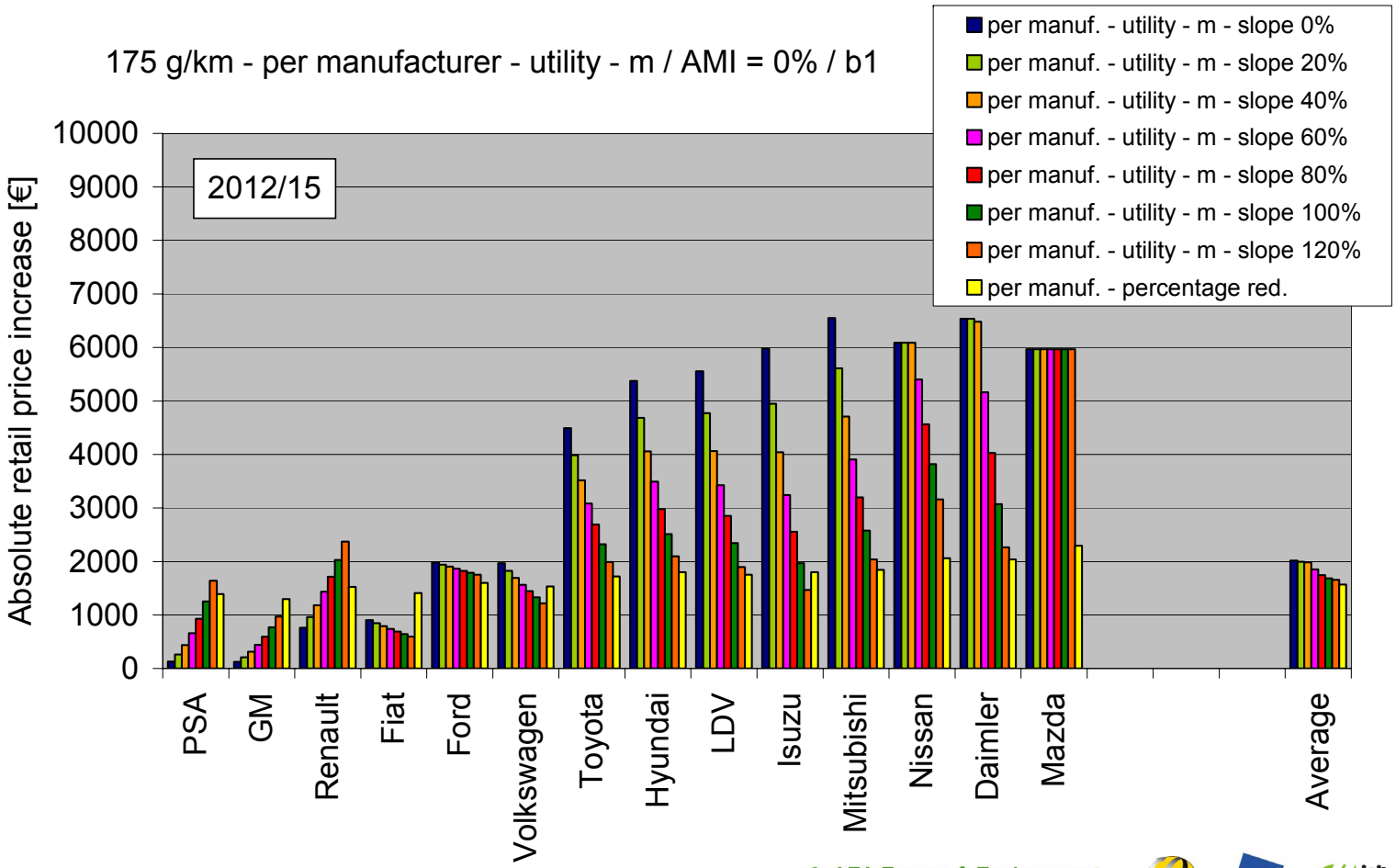
| utility = reference mass | | | 2012 average CO2 emission | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| target | year | AMI | target definitions | | | | | | | | |
| [g/km] | | p.a. | 0% | 20% | 40% | 60% | 80% | 100% | 120% | 140% | percentage |
| 175 | 2012 | 0.0% | 176,4 | 175,8 | 175,1 | 175,1 | 175,0 | 175,0 | 175,0 | 175,0 | 175,0 |
| 175 | 2015 | 0.0% | 176,4 | 175,8 | 175,1 | 175,1 | 175,0 | 175,0 | 175,0 | 175,0 | 175,0 |
| 160 | 2015 | 0.0% | 164,3 | 163,4 | 162,6 | 161,8 | 161,1 | 160,5 | 160,2 | 160,3 | 160,0 |
| 175 | 2012 | 1.5% | 178,0 | 177,2 | 176,4 | 175,7 | 175,2 | 175,1 | 175,1 | 175,1 | 175,0 |
| 175 | 2015 | 1.5% | 179,1 | 178,2 | 177,4 | 176,5 | 175,8 | 175,3 | 175,1 | 175,2 | 175,0 |
| 160 | 2015 | 1.5% | 169,2 | 168,3 | 167,6 | 167,0 | 166,3 | 166,2 | 166,2 | 166,2 | 165,1 |

| utility = pan area | | | 2012 average CO2 emission | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| target | year | AMI | target definitions | | | | | | | | |
| [g/km] | | p.a. | 0% | 20% | 40% | 60% | 80% | 100% | 120% | 140% | percentage |
| 175 | 2012 | 0.0% | 176,4 | 176,0 | 175,6 | 175,4 | 175,4 | 175,4 | 175,4 | 175,4 | 175,0 |
| 175 | 2015 | 0.0% | 176,4 | 176,0 | 175,6 | 175,4 | 175,4 | 175,4 | 175,4 | 175,4 | 175,0 |
| 160 | 2015 | 0.0% | 164,3 | 163,9 | 163,5 | 163,1 | 162,7 | 162,3 | 162,0 | 161,9 | 160,0 |
| 175 | 2012 | 1.5% | 178,0 | 177,6 | 177,2 | 176,8 | 176,3 | 176,2 | 176,2 | 176,2 | 175,0 |
| 175 | 2015 | 1.5% | 179,1 | 178,7 | 178,3 | 177,9 | 177,4 | 177,0 | 176,8 | 176,8 | 175,0 |
| 160 | 2015 | 1.5% | 169,2 | 168,7 | 168,3 | 168,0 | 167,7 | 167,4 | 167,1 | 167,1 | 165,1 |

< 1 g/km above target
1 - 2 g/km above target
> 2 g/km above target

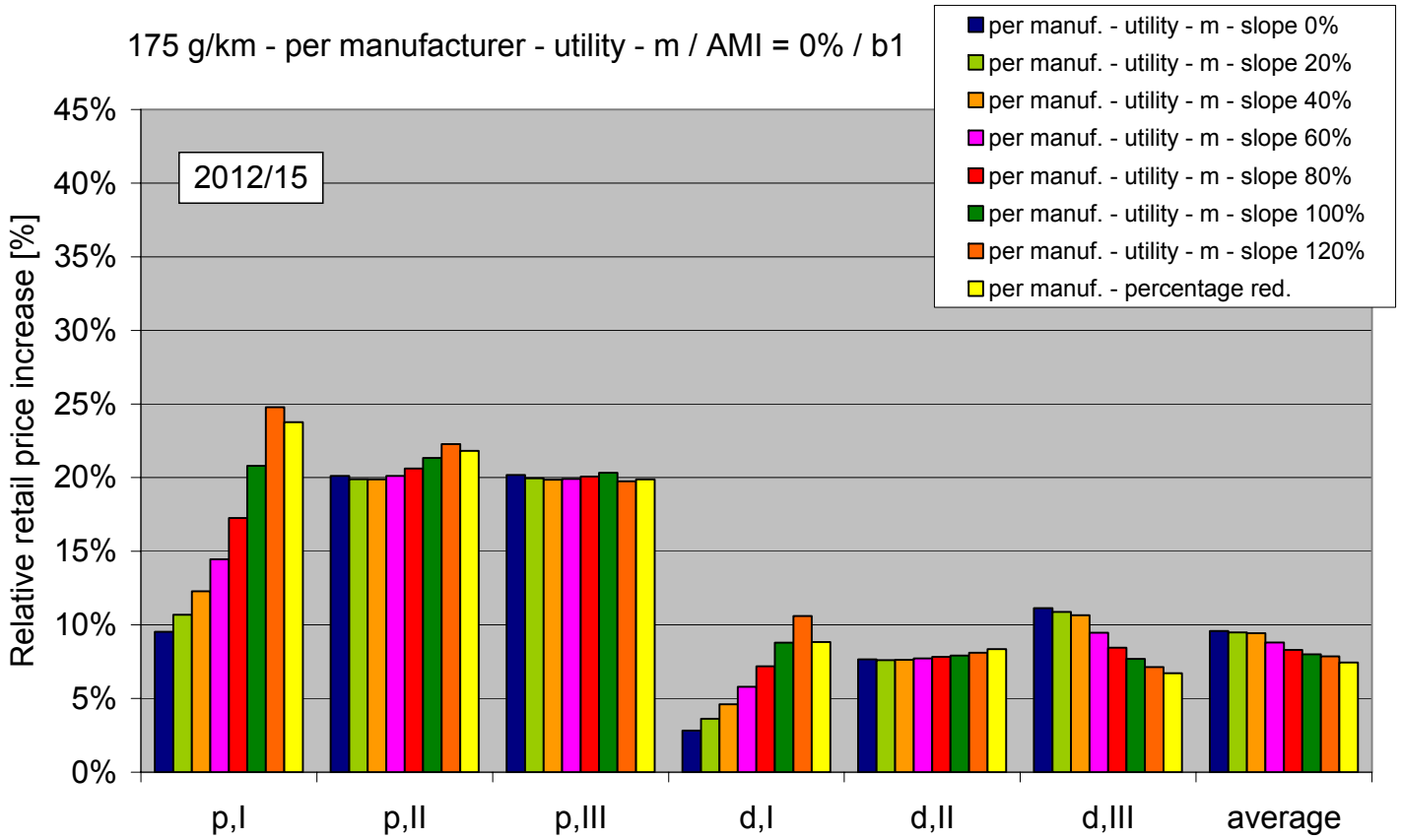
# LCVs & $CO_2$ | Results of cost assessment

- example of distributional impacts:
  - 175 g/km in 2012/15, mass-based, AMI = 0.0% p.a.



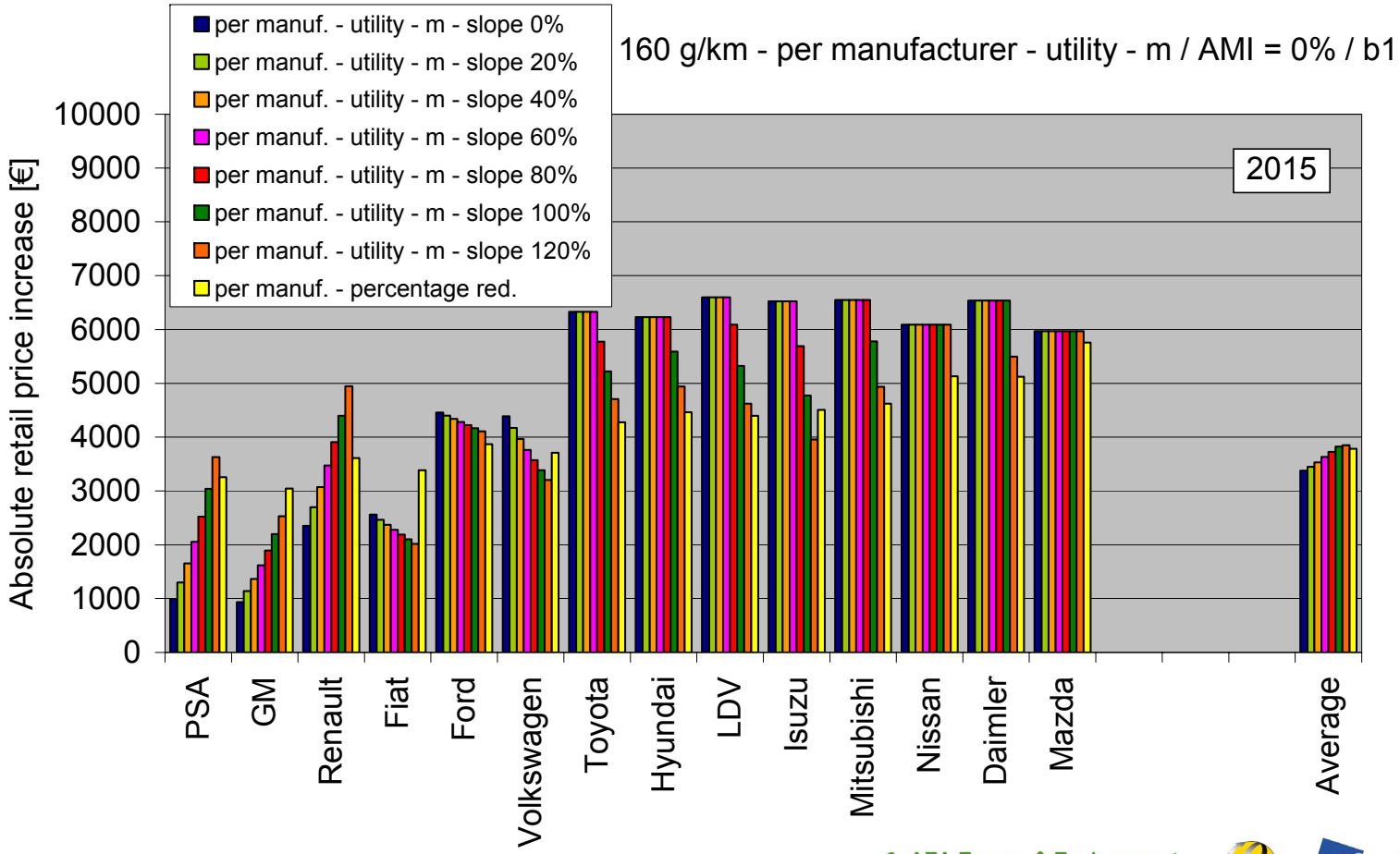
# LCVs & $CO_2$ | Results of cost assessment

- example of distributional impacts
  - 175 g/km in 2012/15, mass-based, AMI = 0.0% p.a.



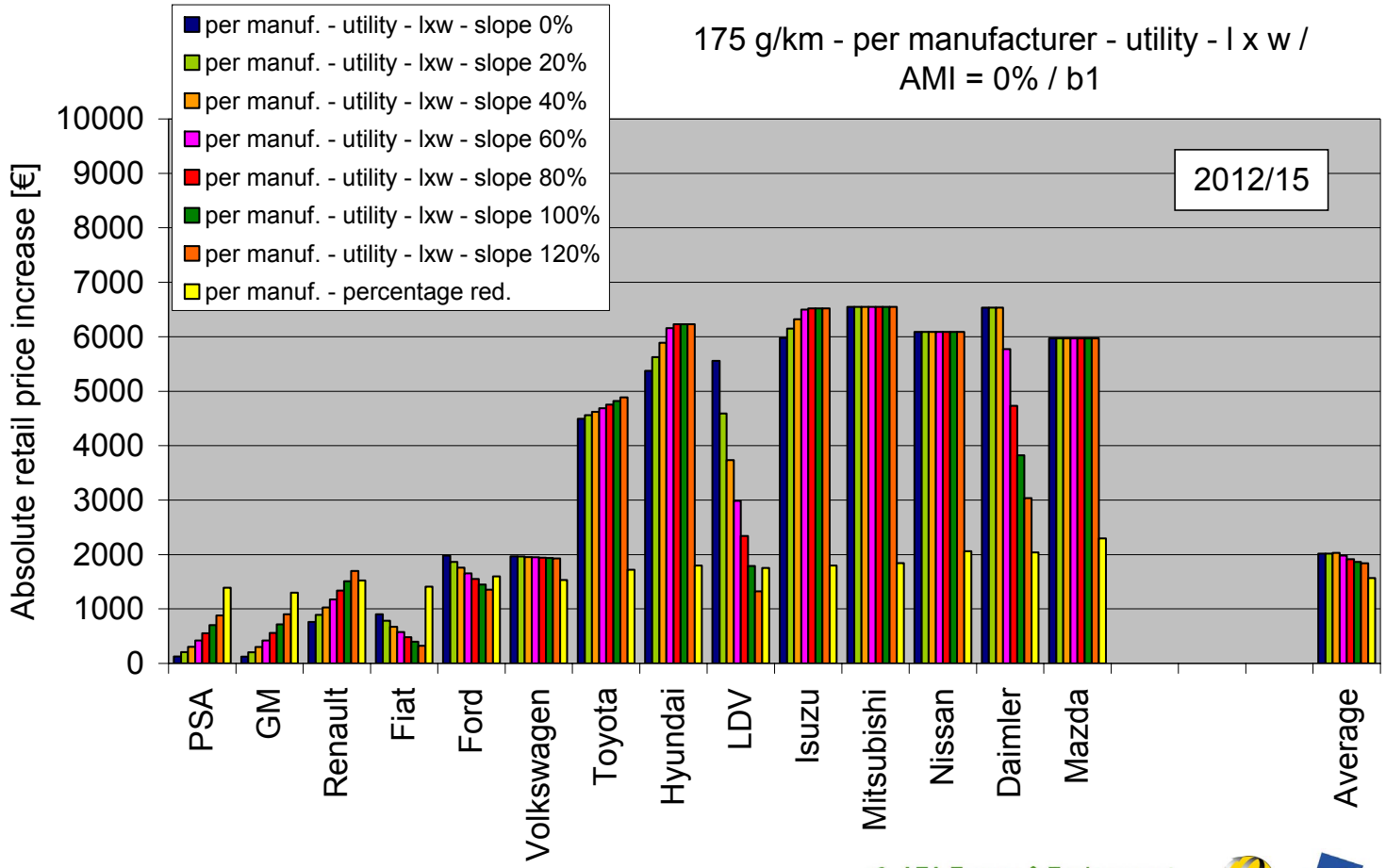
# LCVs & $CO_2$ | Results of cost assessment

- example of distributional impacts
  - 160 g/km in 2015, mass-based, AMI = 0.0% p.a.



# LCVs & $CO_2$ | Results of cost assessment

- example of distributional impacts:
  - 175 g/km in 2012/15, pan area based, AMI = 0.0% p.a.



# LCVs & $CO_2$ | Results of cost assessment

- comments:
  - high reductions in petrol segment can be considered artefact of modelling approach
    - will not happen in practice due to low sales numbers
    - has negligible impact on cost analysis
  - some manufacturers have more difficulty than others in reaching target, mostly related to large pick-ups in LCV sales
  - if overall target is not met, costs of various target definitions can not be accurately compared

# LCVs & $CO_2$ | Results of cost assessment

**Conclusions**:

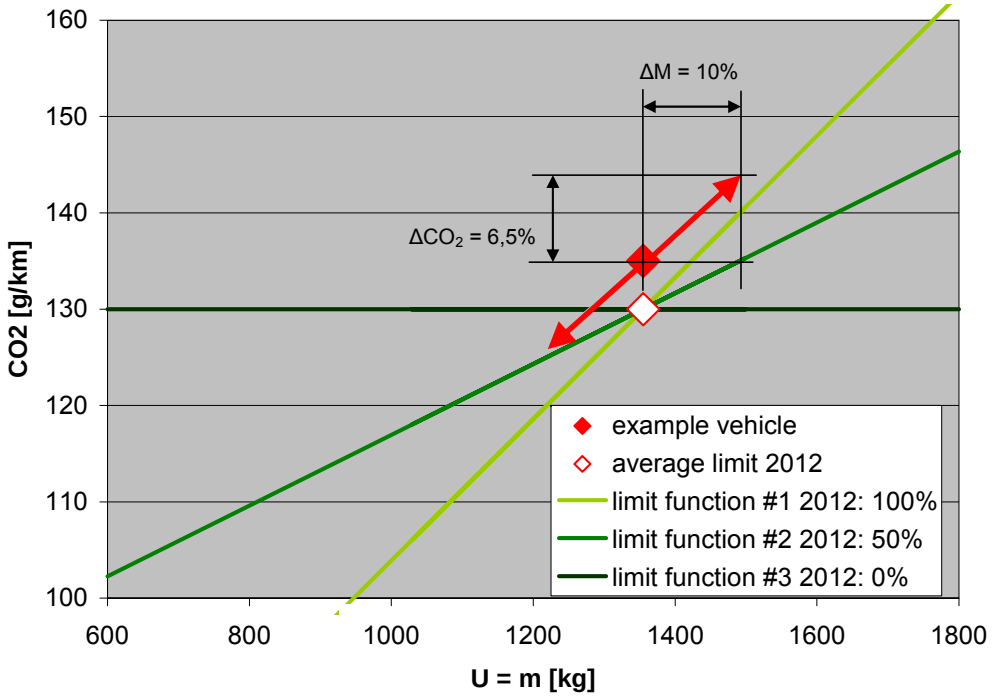
- mass-based limit function with slope ≥ 80% leads to:
  - lowest average costs per vehicle for meeting target
    - € 1650 – 1750 (8 - 9.5%) per vehicle for 175g/km in 2012/15 with AMI = 0.0%
    - € 3050 – 3120 (13 - 15%) per vehicle for 175g/km in 2015 with AMI = 1.5.0%
  - equal distribution of efforts among manufacturers
- non-zero AMI has strong impacts on costs
  - but non-zero AMI less likely in vans compared to M1
- pan area based limit function leads to:
  - higher costs for meeting target
  - stronger distributional impacts

# LCVs & $CO_2$ | Perverse incentives

- high slope of mass-based limit function may create incentive to increase mass in order to reduce required $CO_2$ reduction effort
- general principles similar to M1 case

*example from M1 analysis*

$\Delta CO_2 / CO_2 = \gamma \times \Delta m / m$



# LCVs & $CO_2$ | Perverse incentives

- option 1: simply add weight (“brick in the boot”)
  - γ = 0.35
  - goes at expense of payload
  - slope < 30% needed to avoid this
- option 2: add weight and compensate power to maintain performance
  - γ = 0.65
  - makes cars more expensive, trend in LCVs unknown
  - slope < 60% needed to avoid this
- option 3: sell heavier, more luxurious and more powerful cars (increase power-to-weight ratio)
  - γ > 0.65
  - very unlikely for rational LCV market

# LCVs & $CO_2$ | Perverse incentives

Conclusion:

- advantages of using a slope of 80% or more, as identified in the cost assessment, can be considered to outweigh the possible perverse incentives for mass increase provided by higher slope values for the mass-based limit function

# LCVs & $CO_2$ | Conclusions

- 175 g/km target can be reached in 2012/15
  - at around 10% retail price increase
- 160 g/km target not feasible for 2015
  - based on static cost curves for 2012-15 period with conservative safety margin for assessing total reduction potential for combined measures
  - assessment of LT target for 2020 still on-going
    - analysis will include additional technological options and cost reduction as function of cumulative production due to learning effects
- mass-based limit function with slope ≥ 80% preferred due to:
  - lowest average costs per vehicle for meeting target
  - most equal distribution of efforts among manufacturers
  - limited chance of perverse effects compared to M1
- non-zero AMI has strong impacts on costs
  - impacts on $CO_2$ corrected by adjusting limit curve

# LCVs & $CO_2$

Thank you