Assessment of cost effectiveness from different perspectives of reducing CO_2 emissions from LDVs

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Introduction


Introduction

- The regulatory metric used in the Regulations to reduce LDV CO_2 emissions may differentially promote certain drivetrain technologies
  - In a Tank-to-Wheel (TTW) CO_2 related regulatory system, vehicles with very low TTW emissions are very beneficial for manufacturers to meet their targets, regardless of their Well-to-Tank (WTT) emissions
  - However, such vehicles may not be the most cost effective way to reduce overall transport CO_2 emissions from a societal perspective
- To ensure policy cost-effectiveness, its necessary to understand manufacturer responses to different regulatory metrics, and the consequences for Well-to-Wheel (WTW) CO_2 emission reduction
- These are the objectives of the analysis

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Coverage of the assessment

Regulatory metrics:

- CO_2 based
  - TTW (TTW gCO_2/km)
  - WTW (WTW gCO_2/km)
- Energy based
  - TTW (TTW MJ/km)
  - WTW (WTW MJ/km)

Drive trains:

- conventional/hybrid (ICEV)
  - petrol, diesel
- Low CO_2-Emitting Vehicles (LEV)
  - Plug-in hybrid (PHEV)
  - Battery electric (BEV)
  - Fuel cell (FCEV)

For simplification purposes, the term **LEV** is used to describe the overall category of powertrains with low TTW CO_2 emissions.

All figures used and targets assumed are for illustrative purposes only

The model

Assessing manufacturer response to target

- Predicting specific OEM responses not possible as wide range of considerations determine chosen compliance strategy

- Simplified modelling approach:
  - OEMs strive to minimize additional manufacturer costs
  - But end-user interest more related to Total Cost of Ownership (TCO)
    - Without LEVs the solution with minimal additional manufacturer costs to 1st order also leads to minimal TCO
    - With LEVs correlation between cost impact from perspectives of OEMs and end-users are less well correlated
  - For OEMs the optimal LEV share will be somewhere between optima for additional manufacturer costs and TCO

The assessment tool

- Possible manufacturer responses are explored based on the assumption that costs would be minimised from a:
  - manufacturer perspective (Δ manufacturer costs) and/or
  - end-user perspective (ΔTCO)
- It can then be assessed whether LEV shares with minimal costs from these perspectives align with LEV shares with:
  - minimal societal abatement costs
  - maximum WTW CO_2 emission reduction
- Assess sensitivity of costs for over/undershooting optimal LEV shares


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The assessment tool: methodology

- Equivalent targets are defined for each metric based on assumed technology contributions and TTW and WTW data

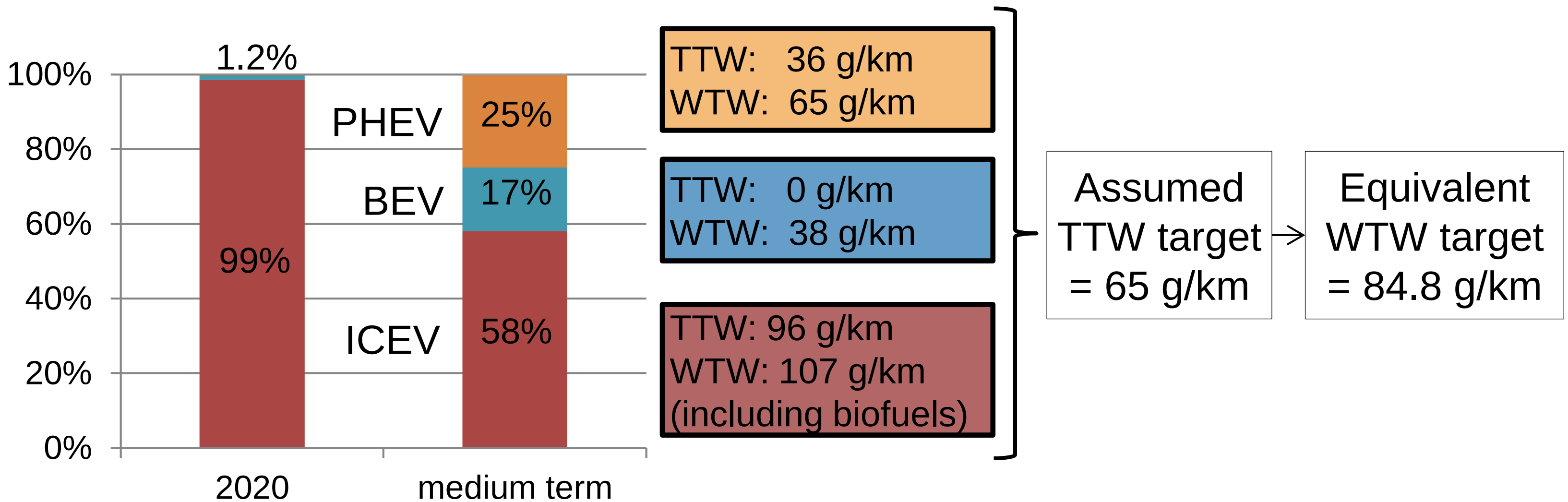
- Only one LEV alternative to ICE is considered at a time
- For each target and metric the impact of a range of LEV shares is considered
- The share of LEVs and their performance on the metric define effective target for ICEVs

- Per LEVs share the following impacts are calculated:
  - *OEM-perspective:* additional manufacturer costs
  - *user perspective:* change in Total Cost of Ownership (ΔTCO)
  - *societal perspective:* societal costs, WTW GHG emission reduction and GHG abatement costs

Assumptions on cost curves for ICEVs, costs and energy performance of LEVs, lifetime, mileage, fuel prices, discount rates, etc. are specified in report


Calculating equivalent targets for the metrics (1)

- Aim at equivalent stringency of targets for different compared metrics
- Based on assumptions about future new vehicle fleet and average emissions / energy use per powertrain type
  - ICEV and LEV shares in new vehicle fleet for 2020 and medium term (2030) reconstructed from data underlying White Paper
  - Allowed 2020 ICEV emissions are 96.3 g/km TTW, because of 1.2% BEVs



Equivalent targets for alternative metrics (2)

- Targets for other metrics are determined for 2020 and for various levels of stringency for the medium term

Equivalent targets in central scenario (Sultan WTT factors)	2020	medium term		
TTW [gCO_2/km]	95.0	75.0	65.0	55.0
WTW [gCO_2/km]	107	91.8	84.8	77.8
TTW [MJ/km]	1.35	1.16	1.07	0.976
WTW [MJ/km]	1.72	1.62	1.56	1.49

Scenarios for analysing sensitivity to variations in input parameters

<table>
<tr><th>Targets 2030</th><th>65 g/km
(Sultan WTT factors)</th><th>55 g/km
(Sultan WTT factors)</th><th>75 g/km
(Sultan WTT factors)</th><th>55 g/km
(SR4 WTT factors)</th></tr>
<tr><td rowspan="9">Scenarios</td><td>Central</td><td rowspan="9">Central</td><td rowspan="9">Central</td><td rowspan="5">Reconstruction of the White Paper</td></tr>
<tr><td>Higher battery cost</td></tr>
<tr><td>Higher electric energy use</td></tr>
<tr><td>Lower WTT factors (except for biofuels)</td></tr>
<tr><td>Higher WTT factors for biofuels</td></tr>
<tr><td>Higher share of biofuels</td><td rowspan="4">Reconstruction of the White paper with higher WTT factors</td></tr>
<tr><td>Equal excise duty for all energy carriers</td></tr>
<tr><td>Higher fossil fuel prices</td></tr>
<tr><td>Lower add. manufacturer costs for ICEVs</td></tr>
</table>

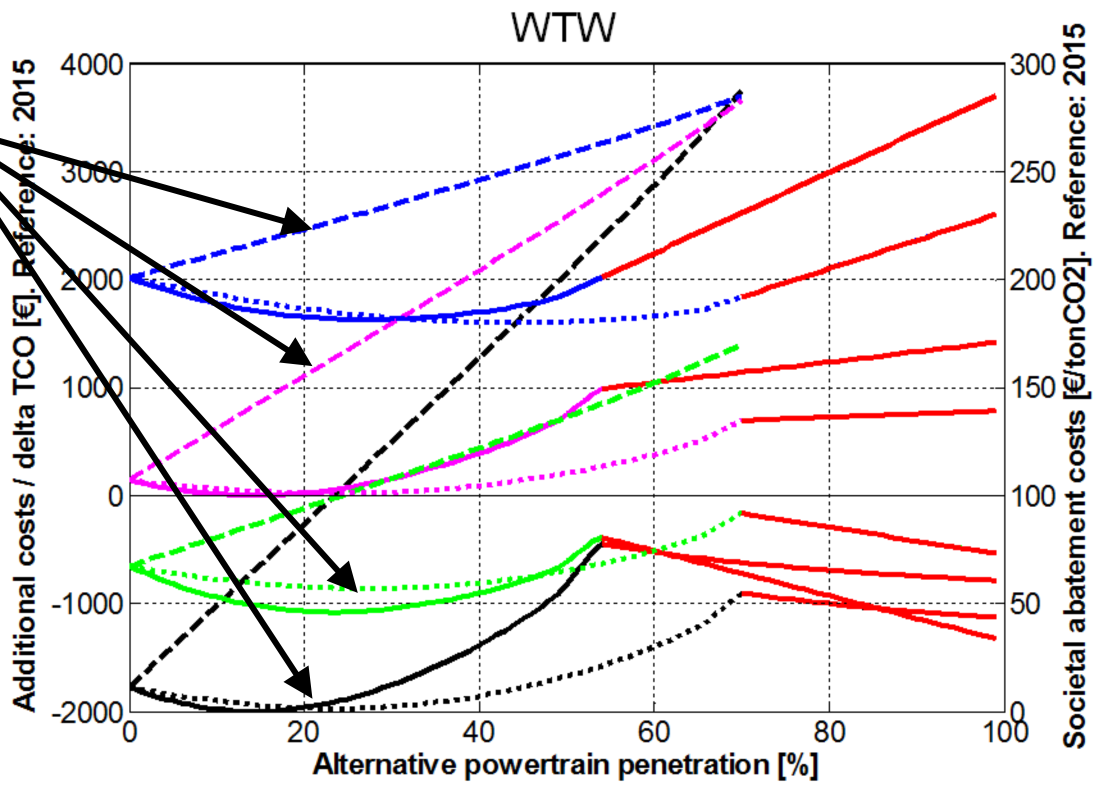

An example

What does the chart show?

costs relative to costs for meeting 130 g/km in 2015

Colour shows perspective:

blue = OEM perspective
green = end-user
magenta = society
black = GHG abatement costs



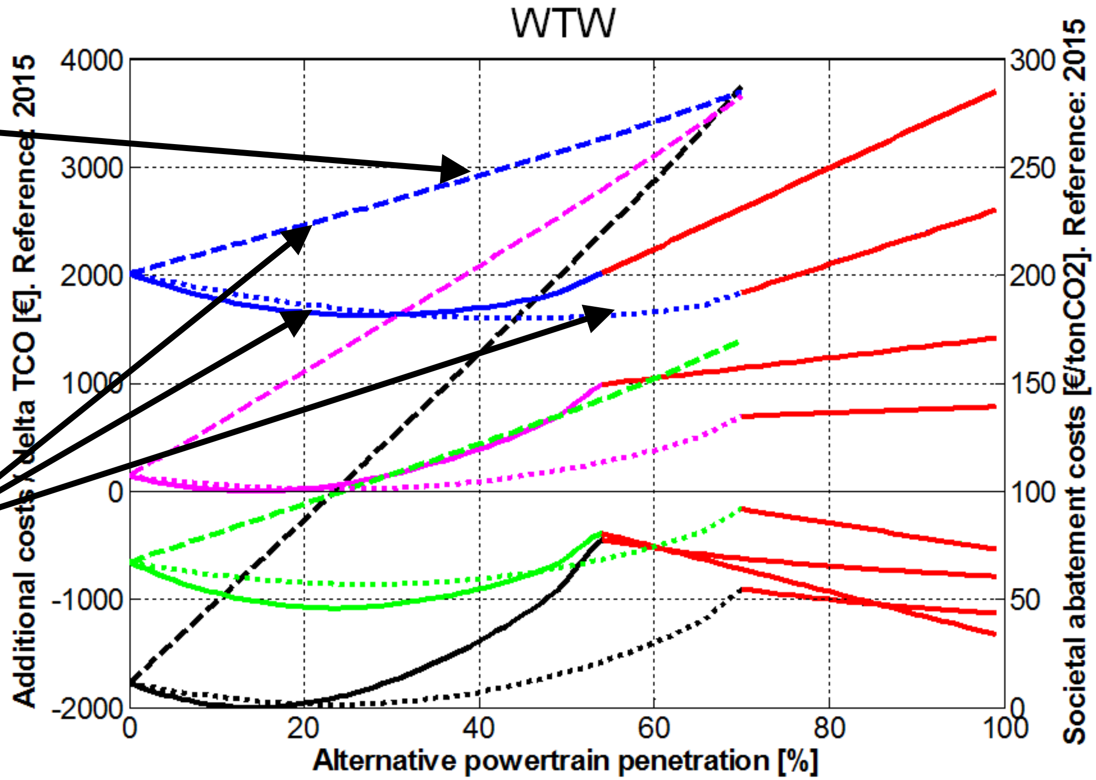
What does the chart show?

costs relative to costs for meeting 130 g/km in 2015

Rising line shows that no share of this LEV-type reduces costs

Line type shows powertrain:

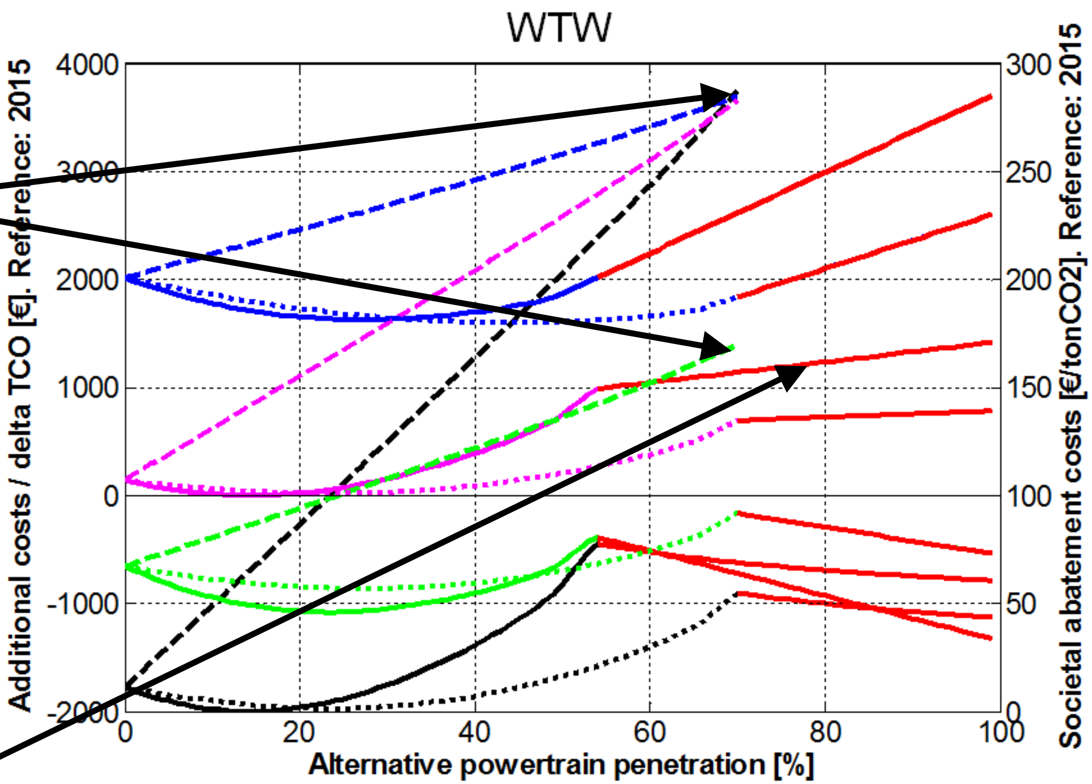
solid = battery electric (BEV)
dotted = plug-in hybrid (PHEV)
dashed = fuel cell (FECV)



What does the chart show?

costs relative to costs for meeting 130 g/km in 2015

No solution possible if ICEVs cannot go below 70 g/km



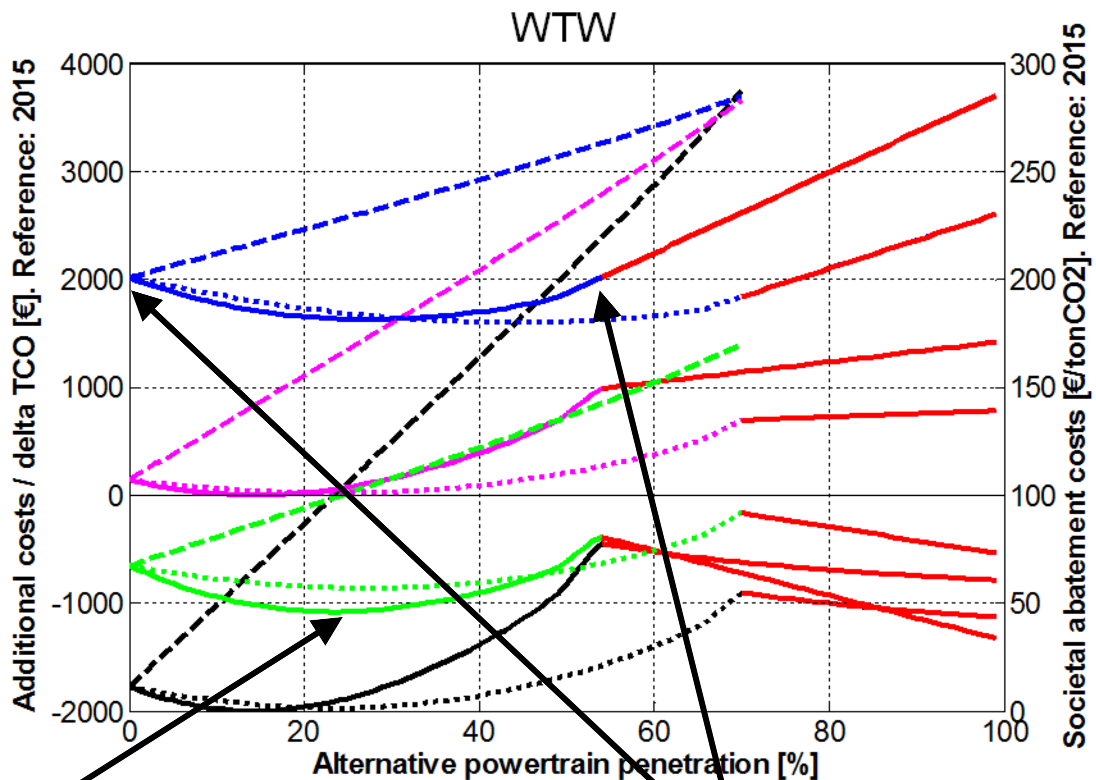
Red lines start when LEV share allows ICEVs to emit 130 g/km

ICEVs capped at 130 g/km

Abatement cost may decrease due to costs decreasing / GHG reduction increasing with further increase of LEV share

What does the chart show?

costs relative to costs for meeting 130 g/km in 2015



Minimum shows optimal point from this perspective

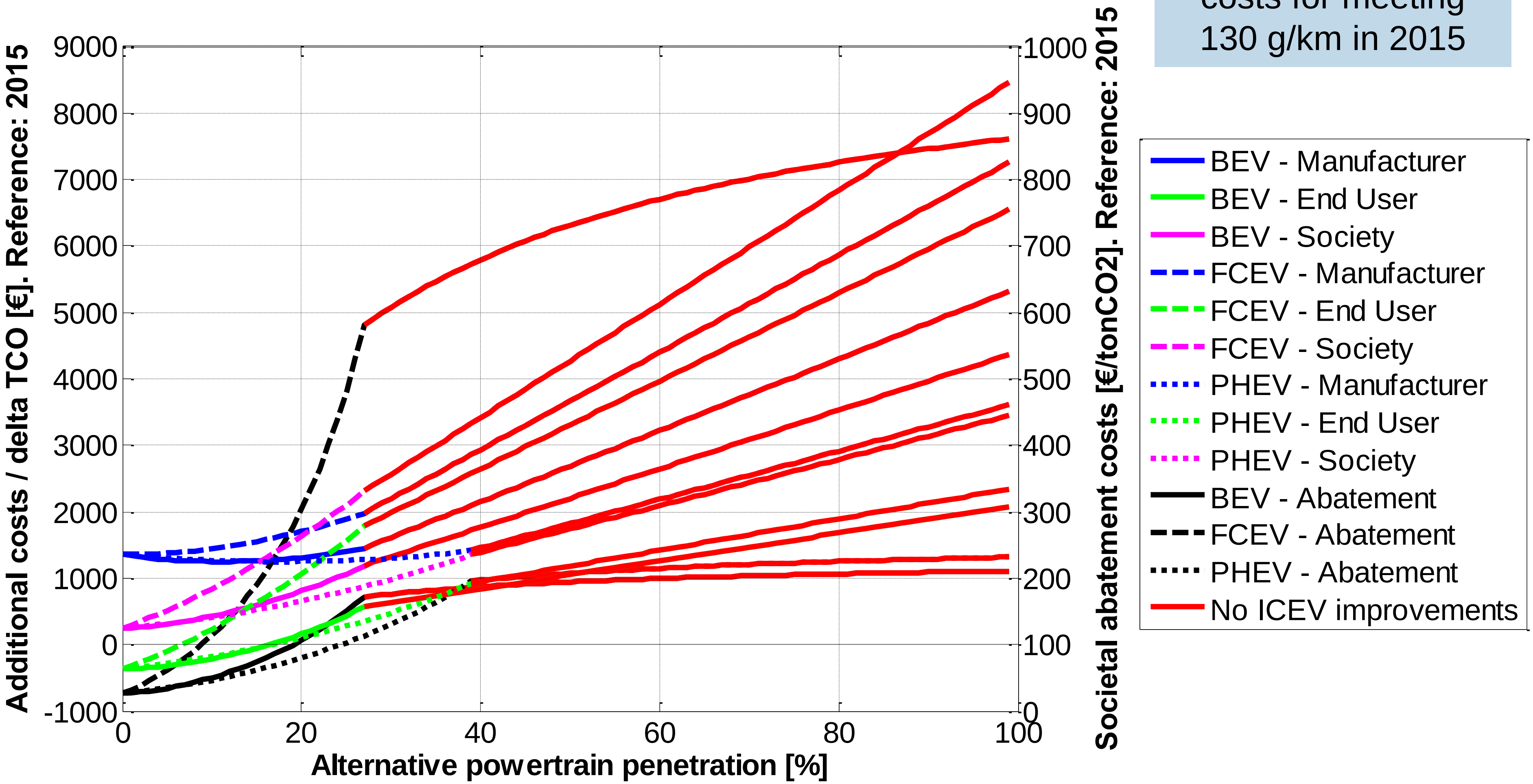
Width of minimum shows sensitivity of costs to LEV share deviating from optimum

TNO innovation for life

year: 2020
target: equivalent of 95 g/km TTW CO_2
metric: **TTW CO_2**
scenario: central

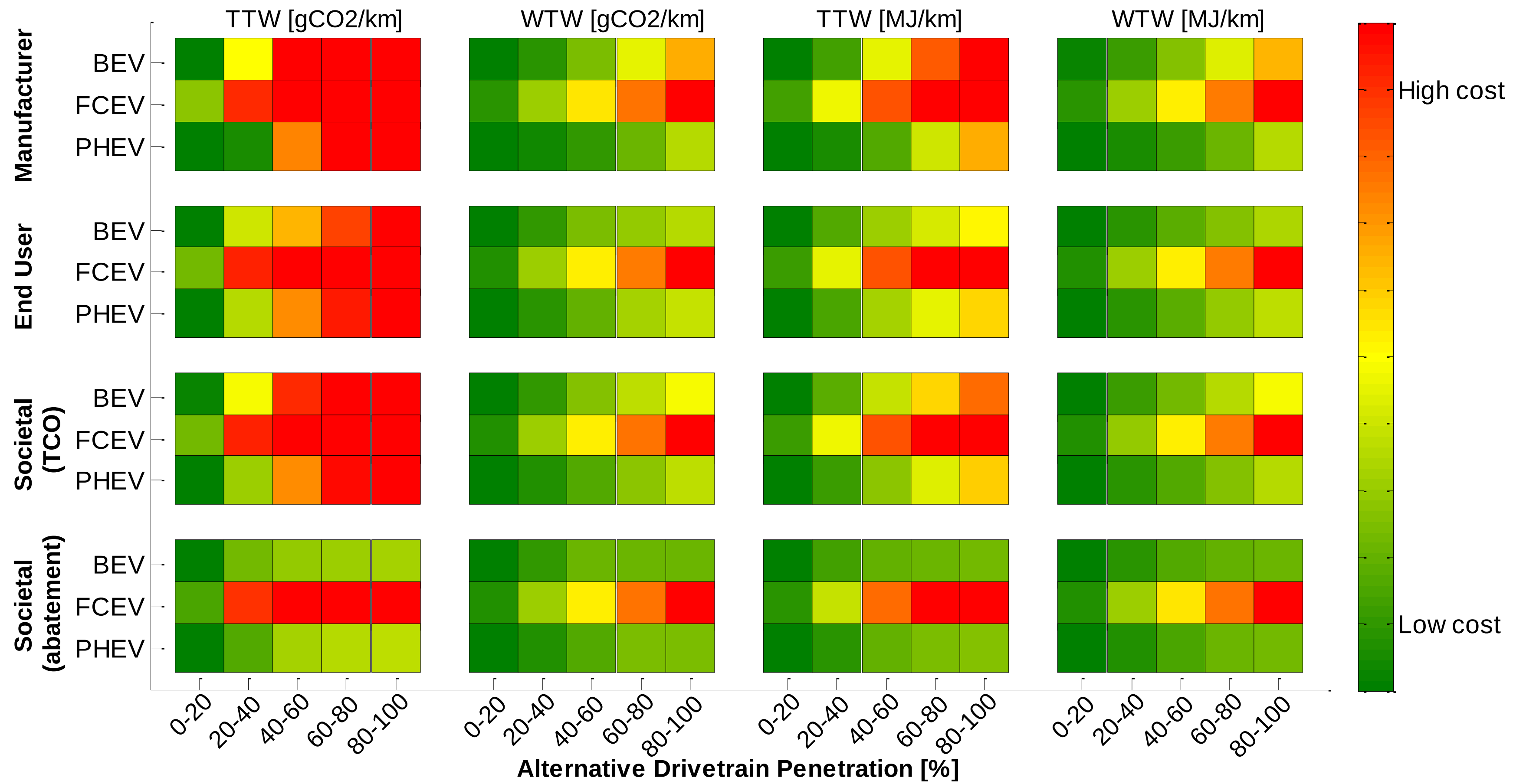
example to explain methodology

costs relative to costs for meeting 130 g/km in 2015



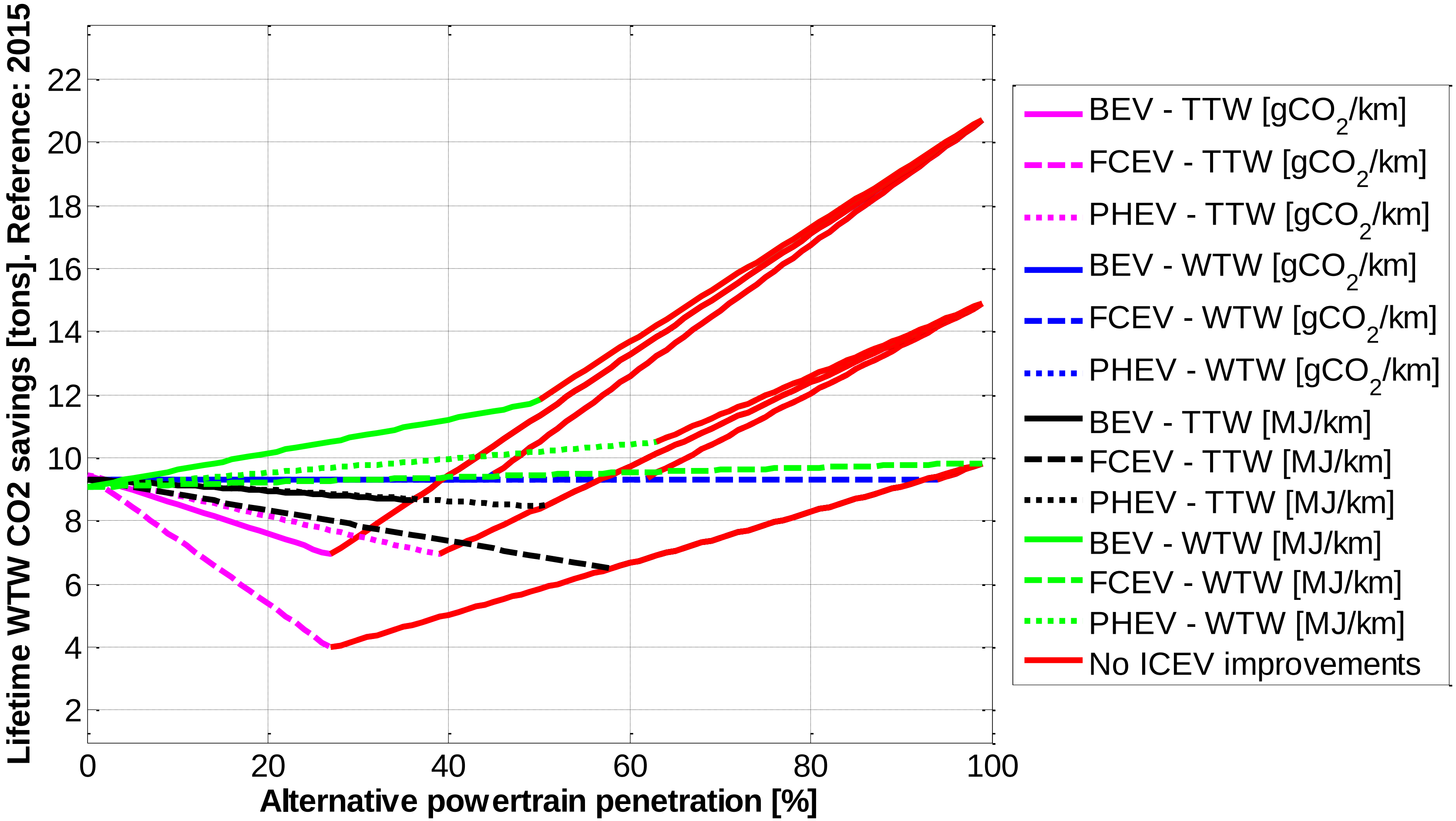
year: 2020
target: equivalent of 95 g/km TTW CO_2
metric: **all**
scenario: central

example to explain methodology



year: 2020
target: equivalent of 95 g/km TTW CO_2
metric: **all**
scenario: central

example to explain methodology



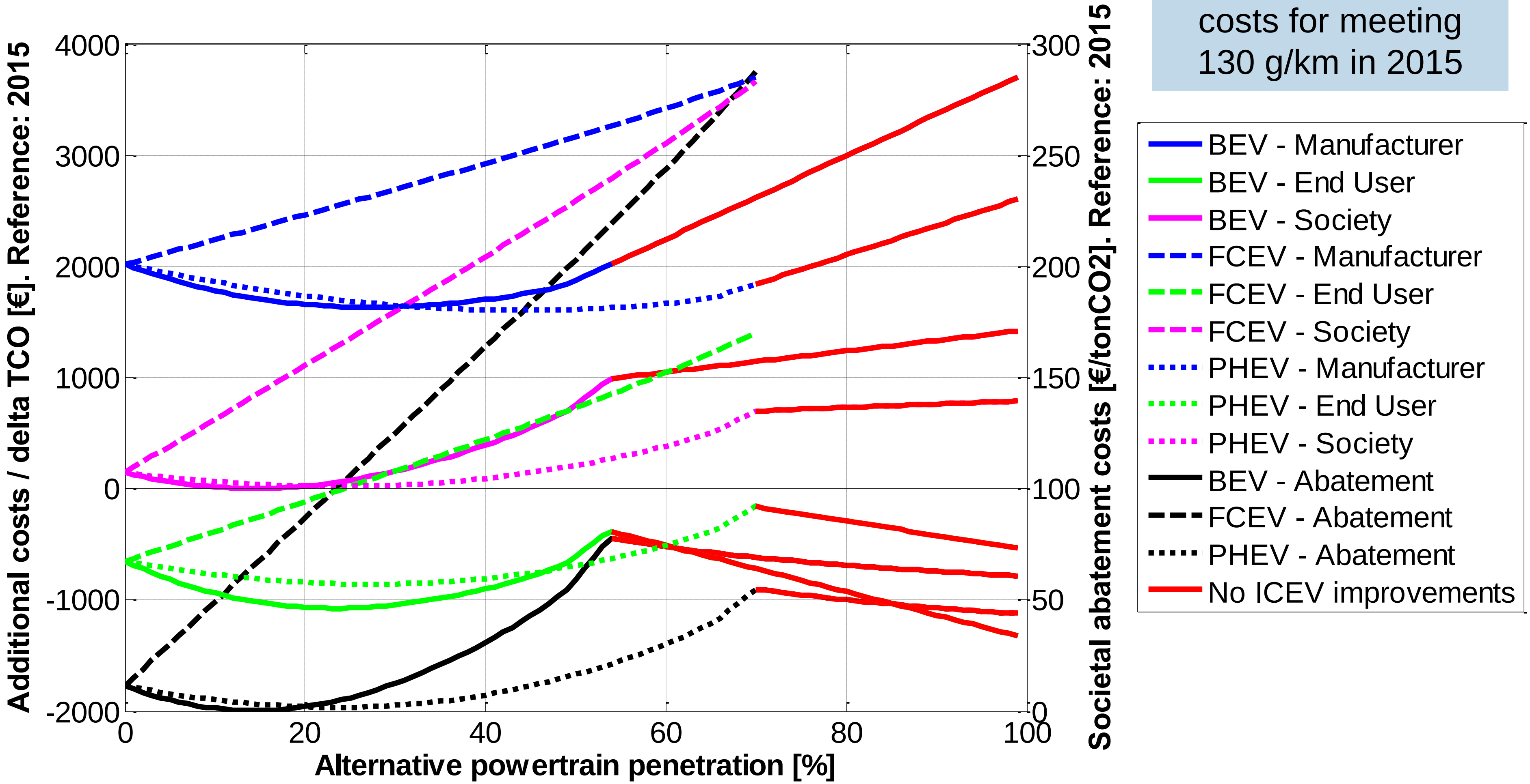

Results

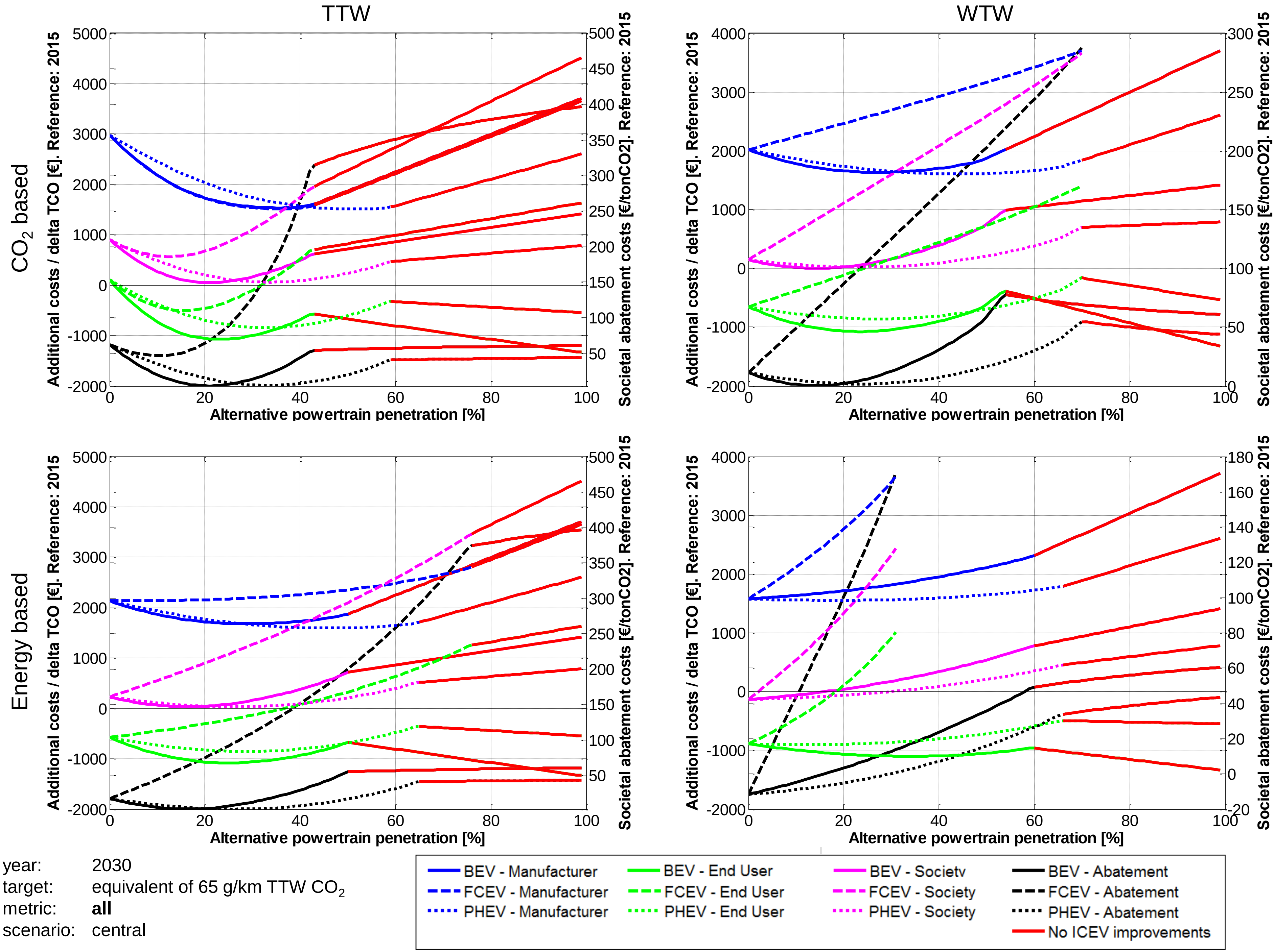
TNO innovation for life

year: 2030
target: equivalent of 65 g/km TTW CO_2
metric: **WTW CO_2**
scenario: central

example
more scenarios assessed in report

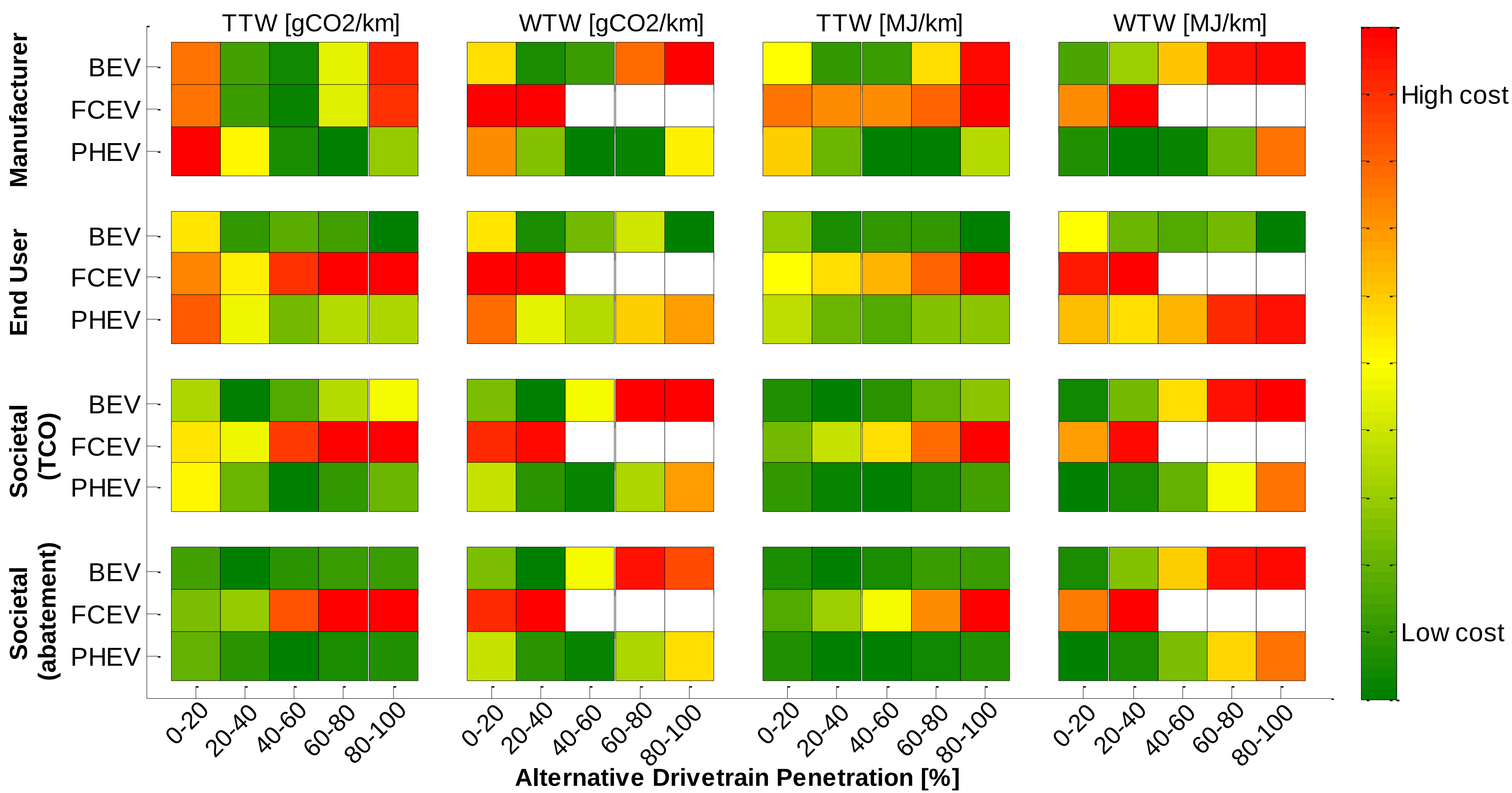
costs relative to costs for meeting 130 g/km in 2015




TTW
WTW
CO2 based
Energy based
Additional costs / delta TCO [€]. Reference: 2015
Societal abatement costs [€/tonCO2]. Reference: 2015
Alternative powertrain penetration [%]
BEV - Manufacturer
FCEV - Manufacturer
PHEV - Manufacturer
BEV - End User
FCEV - End User
PHEV - End User
BEV - Society
FCEV - Society
PHEV - Society
BEV - Abatement
FCEV - Abatement
PHEV - Abatement
No ICEV improvements
year: 2030
target: equivalent of 65 g/km TTW CO2
metric: all
scenario: central

year: 2030
target: equivalent of 65 g/km TTW CO_2
metric: **all**
scenario: central

example
more scenarios
assessed in report



Alignment of cost optima from manufacturer, end-user and societal perspective

- Strong leverage between LEVs and ICEVs under TTW CO_2 metric w.r.t. **Δ manufacturer costs**
  - If price of LEVs lowers sufficiently, producing and selling LEVs becomes a cost effective compliance strategy for OEMs
- For **end users** and **society** leverage is less pronounced
  - Lower CO_2 reductions in ICEVs lead to higher fuel costs
- Difference in cost leverage causes **mismatch** between cost optimal LEV shares from OEM perspective and societal / end user perspective.
  - For the other metrics the alignment with user perspective is better than for TTW CO_2
  - Alignment with societal perspective slightly worse for energy based metrics

Comparison of cost impacts

- Lowest possible **additional manufacturer costs**
  - comparable for all four metrics under all analysed circumstances
  - but costs for the WTW CO_2 based metric sensitive to WTT factors
- Lowest possible **end user costs** also rather similar
  - For WTW energy costs are slightly lower under most circumstances, but overall WTW CO_2 reduction also lower
- Lowest possible **societal costs**
  - Closely related to the end user costs
  - At equal WTW CO_2 reduction the societal costs are very similar for the different metrics
- **WTW CO_2 abatement costs** (cost-effectiveness)
  - different metrics behave very differently
  - insensitive to changes in most of the parameters assessed in this study, except for additional manufacturer costs of technologies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Resilience of the different metrics

Minimally required LEV share

- As a result of assumptions used, TTW CO_2 targets below 70g/km can't be met without a finite share of LEVs
  - TTW CO_2 target of 55 g/km requires > 20% EVs or FCEVs
  - Equivalent targets for the other metrics can be met with no, or only a small share of, LEVs

- Observations very sensitive to how equivalent targets are defined
- Whether it is a pro or con that a metric requires a higher minimum share of LEVs
  - pro: promotions of LEVs
  - con: reduces the technology neutrality

Resilience of the different metrics

Sensitivity of costs for over/undershooting the optimal LEV share

- Metric can be considered more robust if costs for meeting the targets and the net WTW CO_2 reduction do not strongly depend on how exactly the optimal share of LEVs is achieved
  - High leverage of LEVs under TTW CO_2 metric causes relatively high sensitivity of costs for meeting target to deviations from optimal LEV shares
  - On this aspect all alternative metric perform better
  - Conclusion is somewhat sensitive to variations in various scenario parameters, especially for the WTW energy based metric.

Resilience of the different metrics

Sensitivity to higher battery cost

- Optimal LEV shares significantly lower than in central scenario

- From manufacturer and end-user perspective the relative attractiveness of FCEVs compared to BEVs and PHEVs is improved
  - Under TTW CO_2 based metric FCEVs become favourable technology from a manufacturer perspective
  - Under the other alternative metrics, meeting the target with shares of BEVs or PHEVs is still more cost effective than with FCEVs.

- For this scenario results wrt CO_2 emission reductions are the same
- The abatement costs for FCEVs are still higher over the whole penetration range than the abatement costs of PHEVs and BEVs

year: 2030

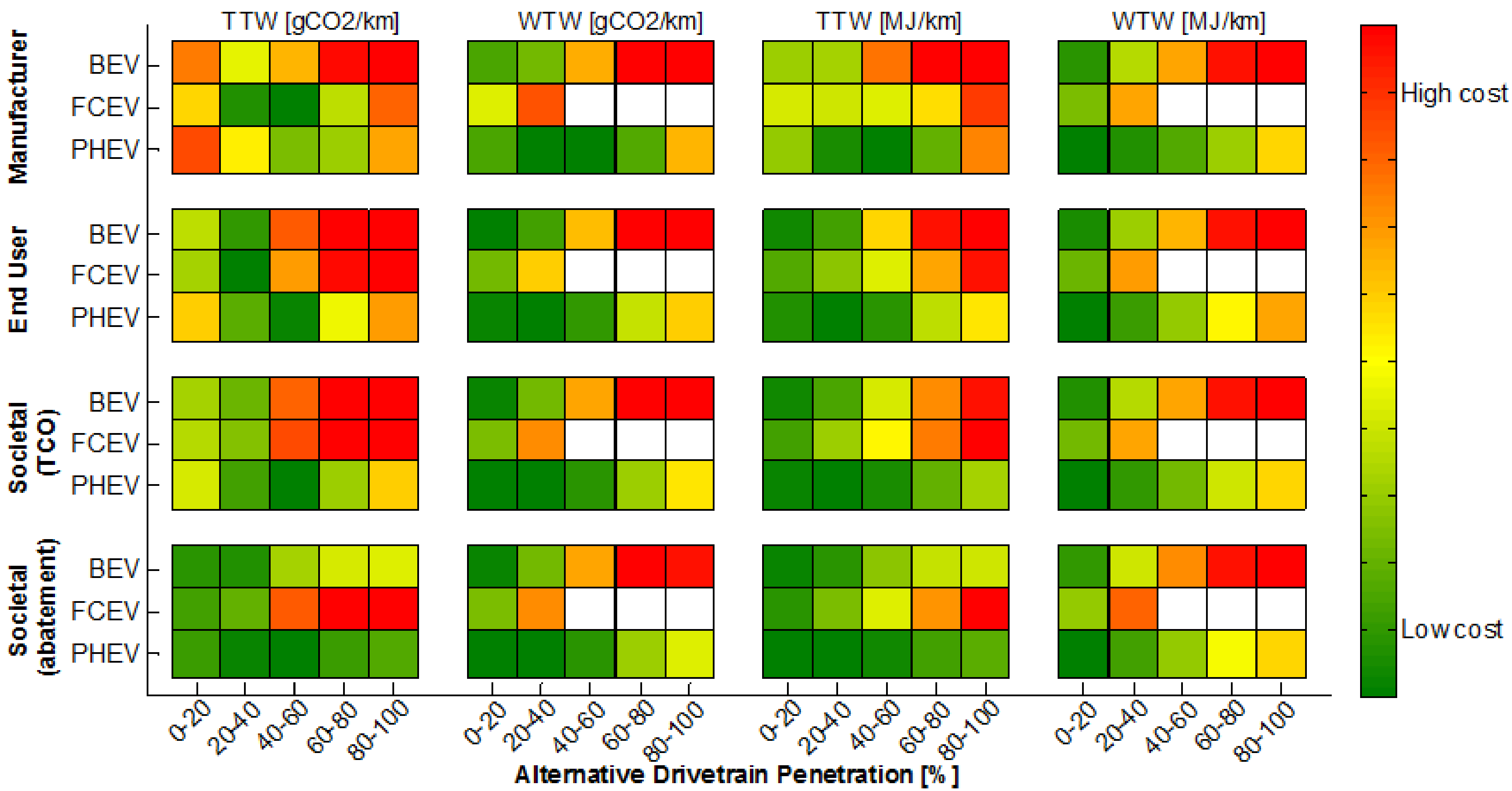
target: equivalent of 65 g/km TTW CO_2

metric: **all**

scenario: higher battery costs

example

more scenarios assessed in report




same slide as in previous presentations

Technology neutrality (1)

- Important guiding principle in the definition of the CO_2 legislation
  - Simple definition: policy defined without specifying technologies with which manufacturers should meet the target
  - Allowing OEMs to choose optimal technologies is believed to lead to highest cost-effectiveness

- Even without explicitly prescribing the use of a certain technology, a policy can implicitly favour or disfavour certain technologies on grounds that are not necessarily consistent with the overall goals
  - E.g. LEVs counting as zero emission under TTW CO_2 target while WTW emissions are non-zero

same slide as in previous presentations

Technology neutrality (2)

- Ideally, for technological neutrality policy should incentivise different technologies proportional to the contribution that each has to meeting the specified overall objective
  - Explored in the graphs by comparing alignment of optimal LEV shares from different cost perspectives and for lowest WTW emissions

- Three alternative definitions of technology neutrality are also considered. These are that OEMs should have the possibility to
  1. meet target with technology of their choice, irrespective of costs
  2. meet the target with multiple technologies at comparable additional manufacturer cost
  3. meet the target with multiple technologies with achievable shares of alternatives

Technology neutrality

1. Possibility to meet target with different technologies at different costs

- Assess how many technologies allow the target to be met (efficient ICEVs, BEVs, PHEVs and FCEVs)
- Assumed that TTW CO_2 based targets <70 g/km cannot be met without a finite share of LEVs
  - => less technology neutral
- For the TTW energy based metric and the WTW CO_2 and energy based metrics all assessed equivalent targets can in most cases be met using either efficiency improvement in ICEVs only (0% share of alternatives) or a finite share of any of the three alternatives.
  - => For this definition of technology neutrality alternative metrics perform somewhat better than TTW CO2 based metric

Technology neutrality

2. Possibility to meet target with different technologies at similar costs

- TTW CO_2 metric can perform very well, as contribution of different types of LEVs is similar, irrespective of the differences in WTT emissions
- Attractiveness to OEM depends on costs of different LEV technologies
- Viewed from other perspectives costs may be rather different

- WTW CO_2 based metric less sensitive to changes in costs, because of smaller leverage of LEVs
- Energy-based metrics perform slightly worse, as the contribution of LEVs to the manufacturer's distance to target is not as proportional to the additional manufacturer costs as under the CO_2 based metrics

- For equivalent targets under the alternative metrics, less LEVs are required to meet the target.

Technology neutrality

3. Possibility to meet target with feasible shares of different technologies

- TTW CO_2 metric performs slightly less well than the others
  - A minimum of 9% of sales should be LEVs to meet 65 g/km TTW target, but is still quite feasible
  - For other metrics, the (equivalents of the) 65 g/km TTW CO2 target can generally be met without LEVs
  - In all assessed scenarios the WTW energy-based targets can be met without any LEVs
    - This metric is most technology neutral from this perspective

- Where in general the scores of different metrics could be very different on the 1st and 3rd definition of technology neutrality, this is not the case in the scenarios assessed here


Incentivising innovation

- Could be considered necessary in view of role of other powertrains to meet 2050 target and long lead times

- Can be assessed by evaluating the LEV shares necessary for meeting equivalent targets for different metrics.

- Most likely that larger shares of such LEVs will be marketed if a post-2020 target would remain based on a TTW CO_2 metric
  - Already significant cross-subsidizing for targets that do not yet require LEVs
  - For lower targets larger LEV shares required than for other metrics

- This criterion may be considered in conflict with the ambition to define CO_2 regulation in a technology neutral manner

Summary

Summary (1)

#	Criteria	Subcriterium	TTW [gCO2/km]	WTW [gCO2/km]	TTW [MJ/km]	WTW [MJ/km]
1	Cost	Lowest cost from manufacturer perspective	o	o	o	o
2		Lowest cost from end user perspective	o	o	o	o
3		Lowest cost from societal perspective at manufacturer/end user cost optimum	o	o	o	+
4	WTW emission reduction	Expected WTW CO2 emission reduction at manufacturers/end users cost optimum	o	o	o	-
5		Avoiding WTW CO2 emission increase as result of increasing share of alternative drivetrains	o	++	+	++
6	Cost effective ness	Lowest abatement cost	o	o	o	+
7		Expected abatement cost at manufacturers/end users cost optimum	o	o	o	+

\+ = better

\- = worse

= options does not meet criterion

Summary (2)

#	Criteria	Alignment of cost optimum from manufacturer	TTW [gCO2/km]	WTW [gCO2/km]	TTW [MJ/km]	WTW [MJ/km]
8	Resilience	Minimally required penetration of alternative technologies	o	+	+	+
9		Alignment of cost optimum from manufacturer and end user perspective	o	++	+	++
10		Alignment of cost optimum from manufacturer/end user perspective and societal optimum	o	+	-	-
11		Limited societal cost difference between the societal cost optimum and the cost resulting from the likely manufacturer and end user response	o	+	o	o/+
12		Limited effect of undershoot/overshoot compared to manufacturer optimum	o	+	+	+
13		Limited effect of undershoot/overshoot compared to end user optimum	o	+	+	+
14		Limited effect of undershoot/overshoot compared to societal optimum	o	+	+	+
15		Limited effect of undershoot/overshoot on WTW CO2 emissions	o	+	+	+

Summary (3)

#	Criteria	Technologies incentiviced proportional to the c	TTW [gCO2/km]	WTW [gCO2/km]	TTW [MJ/km]	WTW [MJ/km]
16	Technology neutrality	Target can be met with multiple technologies	o	+	+	+
17		Target can be met with multiple technologies at comparable additional manufacturer cost	o	o	-	-
18		Target can be met with multiple technologies with achievable shares of alternatives	o	+	+	+
19	Innovation	Promotion of increased application of alternatives (promote innovation)	o	o	o	- -

Observations

- Different metrics have different advantages and disadvantages
- No metric performs significantly better on most or all of the considered aspects

- WTW CO_2 metric performs (almost) equally well as or better than TTW CO_2 metric under the assumptions of the central scenario
- Energy based metrics perform better than TTW CO_2 on some criteria, but notably worse on others.
- WTW CO_2 based metric and the TTW energy-based metric are the least sensitive to changes in analysed circumstances

- According to the modelling approach and the criteria assessed in this study, the WTW CO_2 based metric appears to be the one with which the desired WTW CO_2 reduction is likely to be achieved in the most cost effective way in 2030

Caveats

- A large number (of more qualitative) criteria not considered here, e.g.:
  - support from the stakeholders
  - practical possibility to facilitate the requirements for a certain metric
    - e.g. agreeing on WTT factors to be used for WTW based metric, (periodically) acquiring all necessary information, managing the administrative burden
  - performance of the metric in relation to longer term (> 2030) targets.
- Some of these criteria are taken into consideration in SR4
- Concluding whether the WTW CO_2 based metric is more appropriate than the current TTW CO_2 based metric, therefore requires taking on board a wide range of qualitative and quantitative criteria
  - This would benefit from a broad stakeholder discussion

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Link:

Report available to download at:

http://ec.europa.eu/clima/policies/transport/vehicles/docs/influence_en.pdf