Policy options to maximise zero-emissions vehicle sales in 2035

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Policy brief
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The questions

- What is the impact of future CO_2 emission limits for cars on ZEV sales?
- What are the best additional policies to accelerate ZEV sales?
- What EU policies would optimally support the Dutch ambitions?

Objectives

The objectives resulting from the above key questions are to:

- Understand, through a qualitative evaluation, how the post-2021 CO_2 limits for cars and various complementary policy options influence the market share of Zero-Emissions Vehicles (ZEVs) towards 2035.
- Support the Ministry of Infrastructure and the Environment with its advocacy at the European level by identifying the policy options that optimally support the Dutch ambitions.

Target audience

- The Dutch Ministry of Infrastructure and the Environment, the commissioner of this study.
- Other transport policy makers at national, regional and international level.
- Other stakeholders in the transport sector.

Background

- The European Commission (EC) and the Dutch government call for a 60% reduction in CO_2 emissions in transport by 2050.
- The SER Energy Agreement requires new sales of passenger cars to be 100% 'zero-emissions capable' by 2035.

Challenge

In order for the transport sector to reach its overall 60% CO_2 reduction target, the light-duty sector will need to be virtually emissions-free by 2050. This means that all new cars and vans sold from 2035 on will have to be emissions-free. This is because it takes 15 years before the entire fleet of ICE cars is replaced. Aviation and long haul trucking cannot easily use electricity or hydrogen and will therefore require the vast majority of sustainable biofuels and in addition some fossil fuels. This implies that sustainable biofuels are not a long term option for cars and vans.

Approach

- Explain the current and projected EC regulations on CO_2 limits for cars and several complementary options.
- Project the market share of ZEVs over time, which will depend on the CO_2 emission limits, as well as price developments of both ZEVs and ICE vehicles.
- Evaluate the potential of several complementary options to accelerate the market introduction of ZEVs, in particular their impact on the 'tipping point' year, i.e., the year where ZEVs become more advantageous than ICE vehicles).


BMW

Zero-emissions vehicle (ZEV) definition

- Battery Electric Vehicles (BEVs)
- Fuel Cell Electric Vehicles (FCEVs)
- Excluding bio-fuels/gas
- Including Plug-in Hybrid Electric Vehicles (PHEVs)

Following a consultation with the Ministry of Infrastructure and the Environment, it was decided to use the above definition for ZEVs, i.e., only BEVs, FCEVs and PHEVs. PHEVs use both electricity and fossil fuels. However, it is expected that fossil fuel use by PHEVs will gradually decrease (see next section).

Note that this definition differs from the SER Energy Agreement formulation that newly sold vehicles in 2035 need to be 100% 'zero-emissions capable' by 2035. This formulation is poly-interpretable, as many conventional cars meet this definition if it includes the 'ability to use 100% biofuels'.

It was also was agreed not to differentiate between BEVs, PHEVs and FCEVs. This allows to focus on the key objective: Comparing various policy options.

For the same reason, other starting points were agreed on, notably:

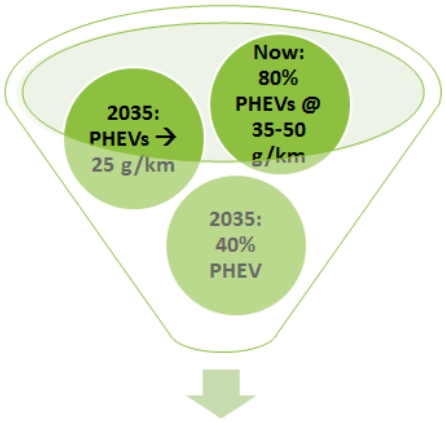
- Only passenger cars considered
- Neglecting phase-in schedules for CO_2 emission limits
- Based on 'CO_2 scale' of the New European Driving Cycle (NEDC).

Note:
The NEDC cycle, which is over 40 years old, results in a large gap between test cycle CO_2 emissions and actual emissions on the road (up to ~40%).

The upcoming World Light-Duty Test Procedure (WLTP) will better reflect the road situation. The WLTP is scheduled (not set!) for 2017. The WLTP will reduce, though not completely bridge, the gap between NEDC values and actual emissions.

The presence of PHEVs in the ZEV park results in emissions of about 10 g/km

Following the starting points of the current study, vehicles introduced from 2035 onwards need to be capable to use electricity or hydrogen as their primary energy source. Electric vehicles comprise both BEVs and PHEVs. The latter are capable to drive on: (1) electricity from the grid, stored in a battery in the car, and (2) fossil fuels. This implies that the average Tank-To-Wheels emissions intensity of the newly introduced vehicles in 2035 will not be zero, as, in addition to electricity, the PHEVs in the car fleet will still use some fossil fuels. In 2035, PHEVs are expected to predominantly use electricity, implying that gasoline or diesel use will be limited to exceptional journeys such as holiday travel.



Resulting 2035 park emissions about 10 g/km

Current PHEV situation
PHEV test cycle emissions ~35-50 g/km

Actual emissions depend on use patterns and electric range of models. Currently ~80% of EVs are PHEVs in NL

PHEV emissions expected to drop
Longer range, better efficiency → Expected 2035 CO_2 intensity: 25 g/km

PHEV market share to go down
As BEVs get a longer range, they displace PHEVs (market share of PHEVs → 40%)

Two parameters will determine the CO_2-intensity of the new vehicles fleet in 2035.

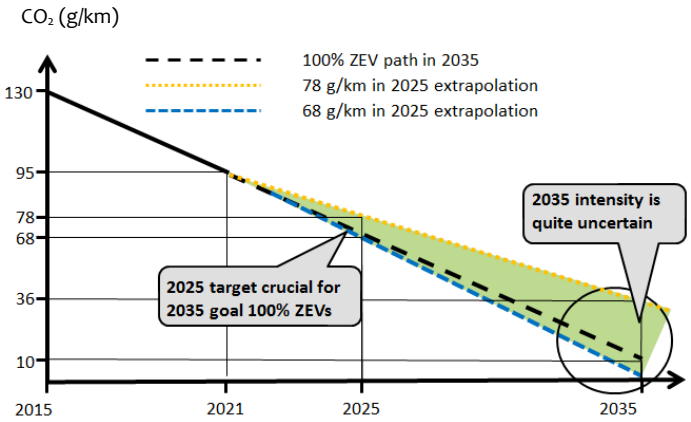
1) The proportion of PHEVs relative to BEVs and FCEVs (both fully electric vehicles). Currently, about 80% of the electric vehicles in the Netherlands are PHEVs (whereas in most other member states this number is much lower). The fraction of PHEVs is expected to drop significantly due to expected range increase of the competing BEVs as well as the introduction of FCEVs. The range increase of BEVs will result from technological advances that improve battery performance. In addition, economies of scale will reduce battery costs. This trend is already visible in announcements from OEMs about upcoming larger BEV ranges.

2) The CO_2 intensity of PHEVs (in gCO_2/km), which is currently in the range of 35-50 g/km, is expected to drop. Average CO_2 emissions of PHEVs depend on the ratio between electrically and fossil fuel powered kilometers. Increasing battery capacities will enhance the all-electric range of PHEVs, while the remaining fossil fuelled kilometers will be driven more fuel efficient due to overall increasing vehicle efficiency. As a result the overall CO_2 intensity of PHEVs will improve.

Taking conservative values of 40% PHEVs and CO_2 emissions of 25 g/km in 2035 leads to average emissions of 10 g/km for newly sold vehicles in that year.

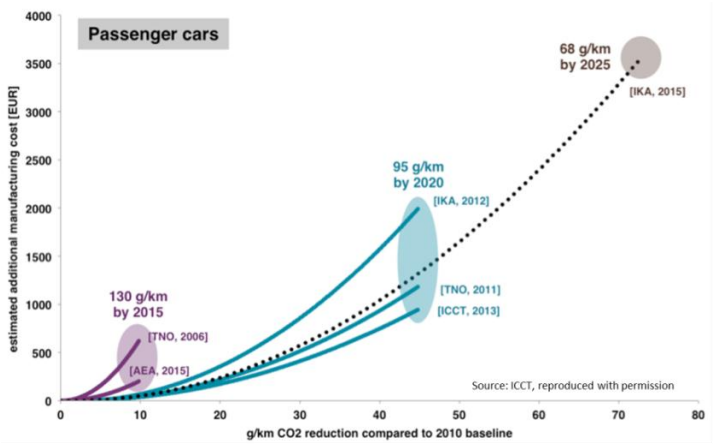
The slope of the CO_2 reduction path controls the rate of ZEV market uptake

The EC has set emissions targets of 130 g/km in 2015 and 95 g/km in 2021. The 2025 targets currently under consideration are 68 (fast option) and 78 (slow option) g/km. As a first order approach we linearly extrapolated the 2025 propositions towards 2035. This leads to 0 g/km in 2035 for the fast option (blue dashed line) and to 36 g/km for the slow option (yellow dotted line). This means that reaching the ambition of 10 g/km for a Dutch zero-emission capable fleet (black dashed line) would require a path close to the fast option. Selecting the slow option would require intensification of the reduction pathway post 2025.



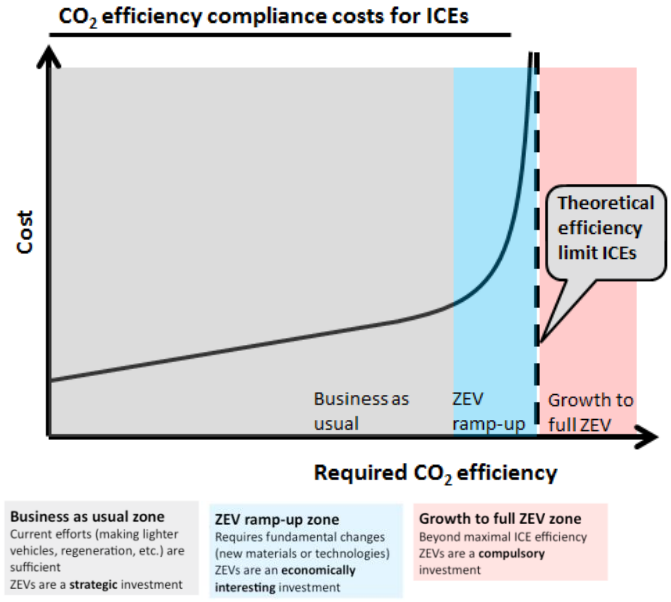
Costs and limits of reducing car CO_2 emissions

As CO_2 emission limits become more stringent over time, OEMs (Original Equipment Manufacturers, i.e. car manufacturers), have to invest in new technologies to meet the stricter targets. Uncertainties about the costs play a key role in the discussion since the Commission in 2009 set the first mandatory CO_2 target of 130 g/km for 2015. Recently the ICCT compiled an overview (see graph) of past and future projections of compliance costs per vehicle (*www.theicct.org/blogs/staff/vehicle-technology-costs-estimates-vs-reality*).



The ICCT argues that ex-ante cost projections based on information and data provided by OEMS and their suppliers (such as the 2015 study by IKA) are substantially higher than the values resulting from ex-post analyses, as well as from alternative detailed approaches also considering other information sources. Following this argumentation, the IKA (2015) estimate of additional cost of about 3500 euro to reach a target of 68 g/km per vehicle could be regarded as an upper limit. Extensive calculations by the ICCT point towards costs of less than 2000 euro per vehicle to reach the 68 g/km. This latter cost estimate would imply that the additional manufacturing costs for meeting the 68 g/km limit, can still be compensated by the fuels savings for car owners during the vehicle lifetime.

Meeting CO_2 limits with ICEs becomes increasingly costly



Meeting CO_2 limits with ICEs becomes increasingly costly over time, and finally becomes impossible when the theoretical efficiency limit of ICEs is approached. At the same time, the conditions for producing ZEVs become increasingly favourable. As indicated in the previous section, for ICEs both the CO_2 reduction costs and their final efficiency limit are not precisely known. This discussion is further complicated by uncertainties about the future test procedures. Nevertheless, the impact of the tightening CO_2 limits can be explained by distinguishing different zones.

Business as usual zone - Tightening emission targets for new sales will have a moderate effect on the strategies of OEMs. In the first years, current efforts, such as making vehicles lighter, or using energy regeneration, would be sufficient to meet the targets. ZEVs would be a long-term strategic investment not essential for meeting short-term targets.

ZEV ramp-up zone - At some point, conventional efficiency improvements in ICEs will not be sufficient and technological breakthroughs will be necessary, at considerably higher costs. Producing ZEVs will then become an economically competitive alternative, for meeting the target, and a choice some OEMs will make.

Growth to full ZEV zone - In the next phase, the efficiency limits of ICEs will be reached, and OEMs will be forced to start producing ZEVs to meet their targets.

Interestingly, the range of the limits proposed for 2025 (68 – 78 g/km), likely approaches the boundaries of the ZEV ramp-up zone (indicated in blue). Having a 68 g/km limit in 2025 would indicatively mean that all OEMs would be forced to start producing ZEVs by then, whereas the 78 g/km limit would delay this but nevertheless incentivise some OEMs to produce ZEVs. However, these boundaries are indicative only, as recent developments suggest that the ZEV ramp-up zone may be stretched to even lower CO_2 intensities, because of uncertainties about both the final technical limits and the impact of future test procedures.

As CO_2 limits become tighter, ZEVs become competitive with ICE vehicles

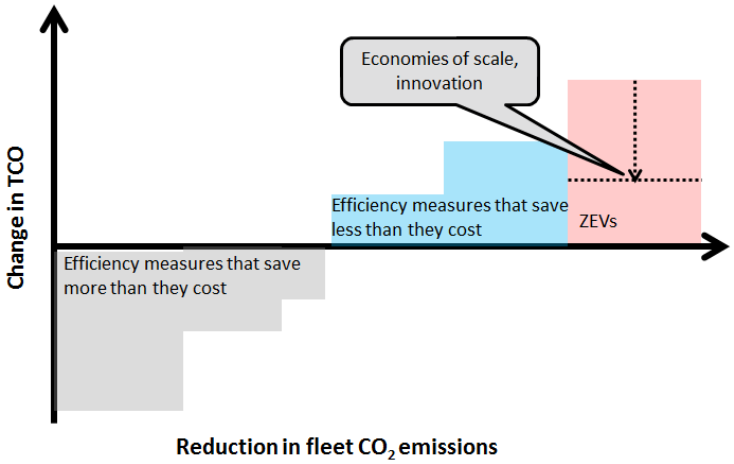
The efficiency improvements in ICE vehicles can be divided into two categories:

1) Efficiency measures that save more than they cost: The extra costs to implement these measures are lower than the fuel savings drivers make during vehicle lifetime. As a consequence, OEMs can pass through (part of) the extra costs, while still delivering a better proposition to their customers (i.e., a lower Total Cost of Ownership (TCO)). Fuel savings are more relevant for lease companies than for consumers, as the average consumer will much more discount future fuel cost savings.

This is the current state of vehicle development and roughly corresponds to the 'business as usual' zone from the previous figure. The customers gain by purchasing more fuel-efficient cars, while OEMs have only limited additional costs that they can (partly) pass through.

2) At some point, the 'low-hanging fruit' measures above will be exhausted, and the fuel savings will become lower than the extra costs to implement measures. That means that OEMs must either reduce their margin or pass extra costs through to their customers that are higher than the fuel savings customers make (and thus increasing the TCO).

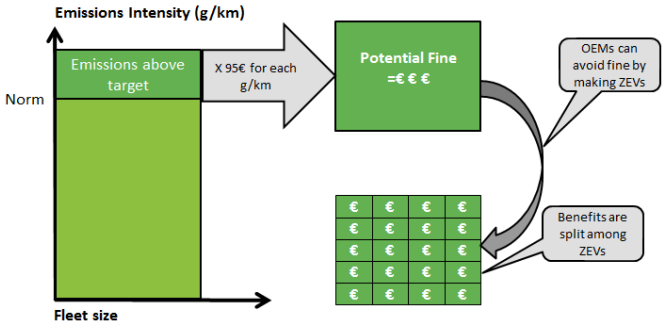
In early development stages, the TCO of ZEVs is considerably higher than the TCO of ICE vehicles. It is even higher than the TCO of very efficient vehicles as described under point 2.



However, the production costs of ZEVs will go down with economies of scale and innovation, bringing the TCO of ZEVs to a competitive level compared to ICE vehicles (which have increasing TCOs, as explained above).

By avoiding non-compliance fines, ZEVs bring value to OEMs

OEMs have to meet the CO_2 limits, based on the average emissions of the vehicles produced in a certain year (in g CO_2/km). If the vehicle fleet produced does not comply with the limit, they have to pay a fine. Non-compliance costs for the 2021 target of 95 g CO_2/km are set at 95 euro for each g CO_2 per vehicle in excess of the norm. For example, as one of the major OEMs misses the target by 1 gram for 1 million of their cars sold in Europe in a certain year, this would result in a fine of up to 100 million euros (based on the 2021 fine level). These are substantial amounts, even for larger OEMs.



Meeting CO_2 limits with ICEs becomes increasingly costly over time. As an alternative, OEMs can produce (more) ZEVs, as the zero-emissions characteristics of these cars effectively 'dilute' the vehicle fleet average emission. The figure on the right visualises how much the ZEV is allowed to cost more than the ICE alternative, based on the fine that should otherwise be paid as a result of non-compliance of the CO_2 limit.

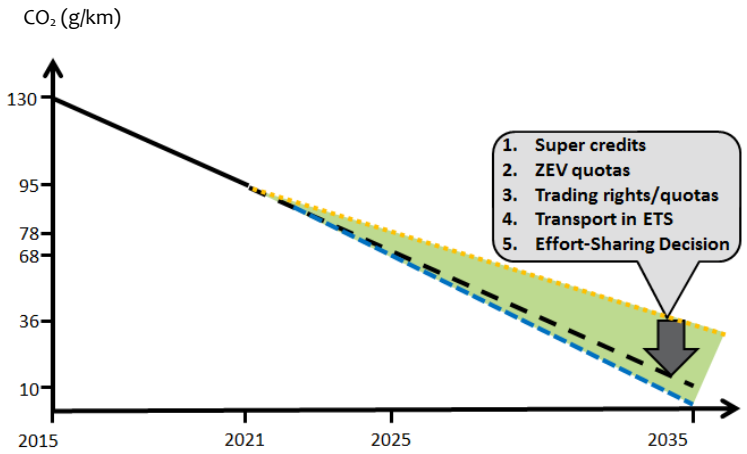
For example, at an emission limit of 100 g/km, an OEM can compensate 100 ICEs that are 1 gram above the limit, by producing 1 ZEV. Assuming a fine of 95 euro per g excess CO_2, the ZEV produced prevents a fine of 100 times 95 euro, or 9500 euro. This example only illustrates the mechanism, since reality is more complex as OEMs have other options to comply, notably by increasing the efficiency of their ICEs. However, as CO_2 limits tighten, compliance by producing ZEVs becomes increasingly financially attractive for OEMs.

What are the best additional policies to accelerate ZEV sales?

As explained in the previous sections, the adoption rate of ZEVs is expected to increase over time due to the combination of:

1) Compliance push (through increasing costs for ICEs to meet the tightening CO_2 limits)
2) Demand pull (as the price of ZEVs becomes increasingly attractive for more customers).

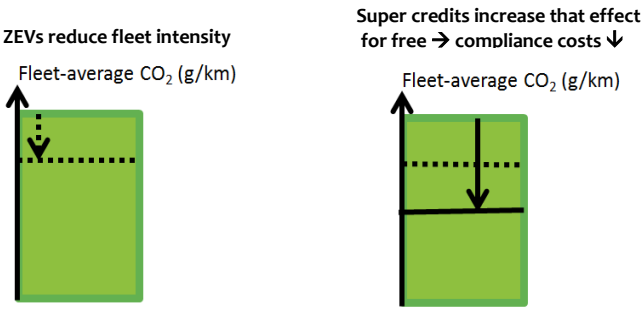
This may induce a 'snowball effect', boosting ZEV sales, that goes above and beyond the impact of the tightening European CO_2 emission regulation. The moment where this boost in ZEV sales occurs will depend on actual cost developments, and can potentially be accelerated with additional policy options.



In consultation with the Ministry of Infrastructure and the Environment it was decided to discuss the following five additional options, towards their potential to enhance the market uptake of ZEVs.

1. Super credits
2. ZEV quotas
3. Trading of emissions rights or quotas
4. Including the transport sector in the European Trading Scheme (ETS)
5. The impact of the Effort-Sharing Decision (ESD).

1) Super credits: Make it more attractive for all OEMs to produce ZEVs



- Factor may be lowered in time: as ZEVs become more viable, less support is needed
- Capped (2020-2022 combined cap is = 7,5 gCO_2/km per OEM)

Note:
The super credit system is actually already in place (for vehicles emitting less than 50 g/km), with factors of 3,5 (2012-13), 2,5 (2014), 1,5 (2015), 1 (2016-2019). The super credit factors for future years are 2 (2020), 1,67 (2021), 1,33 (2022), 1 (from 2023 on). The limit for the use of super-credits, expressed as the difference between average fleet CO2 emissions calculated with and without the application of super-credits, is set at a maximum of 7,5 g/km for the three years 2020–2022 combined.

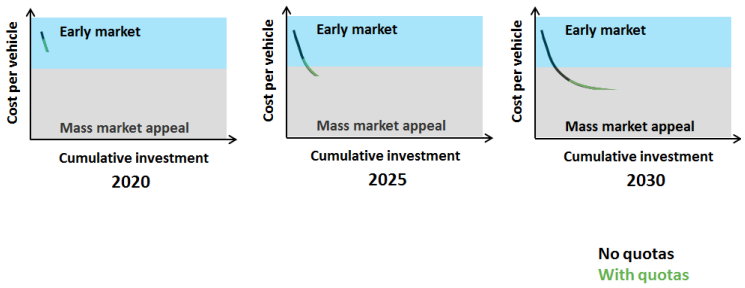
'Super credits' are an administrative CO_2-bonus, temporarily reducing OEMs' CO_2 compliance costs. With super credits, OEMs can administratively report a larger ZEV market share (and consequently a lower ICE market share). As a result, compliance costs go down, so producing ZEVs becomes financially more interesting. It actually increases the financial 'bonus' on a ZEV that is explained on page 12.

The key parameter that will decide the size of the effect is the multiplying factor. OEMs are allowed to use for counting their ZEVs. This factor does not need to be constant, as it would be ineffective to use super credits after the ZEV tipping point has been reached. Rather, it is better to have a larger factor in early stages, where production cost differences between ICEs and ZEVs are high, and to build that down as cost differentials decrease.

In summary, super credits make it more attractive for all OEMs to produce ZEVs.

2) ZEV Quotas: All OEMs are forced to produce ZEVs at the same pace

Quotas force OEMs to invest in ZEVs, even if it is not economically advantageous or if it does not fit their strategic plans. Assuming these quotas are set higher than the optimal pathway for OEMs to meet the emission standard, this will generate economies of scale in an earlier stage, bringing the tipping point to mass-market appeal forward in time.



The figure visualises the impact of ZEV quotas. With ZEV quotas market roll-out of ZEVs will enter the mass-market stage (indicated by the grey zone) earlier. Quotas can be phased out once mass-market appeal is achieved, as by that time ZEVs will have become an economically viable option.

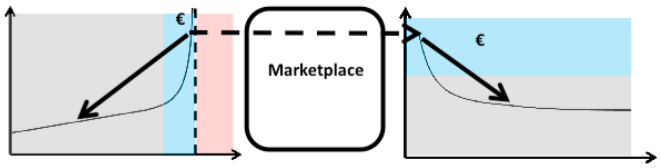
Obviously, ZEV quotas have the drawback of reducing the freedom for OEMs to meet vehicle CO_2 standards in the most cost-effective way. On the other hand, quotas may prevent OEMs from short-sightedly focusing on improving ICE vehicle efficiency only, creating a lock-in effect on the longer term. Essentially, a clear long-term pathway of CO_2 emission standards that are gradually and predictably tightened over the years should be sufficient to create a case for ZEVs.

In summary, ZEV quotas would force all OEMs to produce ZEVs at the same pace. As a result, the ZEV production would reach the mass-market stage earlier. Introducing ZEV quotas could be considered as a complementary option, but only if the European post-2021 CO_2 trajectory lacks ambition and a long-term target.

Note:
California implemented a ZEV mandate that requires OEMs to produce a certain % of ZEVs. By 2025 approximately 15% of all new light-duty vehicles sold in the state are expected to be either electric or fuel cell powered. Nine states have agreed to follow California's ZEV mandate: California and these other 9 states represent ¼ of the US light-duty vehicle market (www.arb.ca.gov/msprog/zevprog/zev prog.htm).

3) Tradable emission rights/quotas: Some champions innovate, some wait

Trading can be allowed for emission rights (related to the CO_2 emission standard) and/or for vehicle quotas. The underlying idea is to shift efforts towards competency cores, allowing for more variation between OEM strategies. Some OEMs will focus on producing ICE vehicles and stay above the emissions limits and/or under a ZEV quota target.



- ICE OEMs reduce CO_2 compliance costs by buying permits from ZEV pioneers
- In later stage, ICE OEMs catch up by getting know-how from ZEV pioneers

- Price is set by the alternative: fines for non-compliance
- Proven mechanisms (e.g. US refineries lead-free fuel)

One of the reasons for them to do so is that they might have a capability advantage in producing ICE vehicles, with their specific technical characteristics. Other OEMs with a strong knowledge position in ZEV related technologies could focus more on producing ZEVs. The trade in allowances between both types of OEMs makes both strategies viable. In a later phase, when ZEVs become a mature and incumbent option, ICE OEMs can catch up by buying ZEV pioneers or licensing their know-how.

The price of tradable allowances will be set by the alternative to non-compliance, i.e., the corresponding fines. Eventually, the progress that ZEV-focused OEMs make in improving processes and reducing costs (including, but not limited to, economies of scale) will propagate to other OEMs starting to produce ZEVs as well. In the past, this type of mechanism has already been successfully implemented to phase out lead use in US refineries. The economic mechanism is comparable to the European Trading Scheme (ETS) for GHG emissions.

In summary, tradable emission rights/quotas would result in some (champion) OEMs that innovate and specialise in ZEVs, while other OEMs will wait. According to economic theory, and proven in other markets, the mechanism would results in overall lower costs.

4) Including transport in the ETS would mean much smaller ZEV production stimulation

The inclusion of transport in the EU-ETS is also under discussion these days. Key considerations:

- From a system perspective, the ETS has the advantage that CO_2 emission reductions are realised in the most cost effective way;
- However, replacing emission standards with the ETS would take away all impetus for reducing CO_2 in transport and introducing ZEVs, until 2030 at least;
- This would leave too little time for creating the transition in transport needed to meet its sectoral 60% reduction target of 2050, a transition in which ZEVs play an inevitable role.

Efficiency standards →

- Provide strong, direct signal for ICE efficiency / ZEV production
- Cost effective for customers
- ZEVs become economically attractive

ETS inclusion →

- Weak, indirect signal. ETS includes sectors with low abatement costs and leakage risk
- 'Energy paradox' remains
- Reaching the 95 g /km technology level would require a CO_2 price > 300 euro/ton => technology standstill.
- 2050 transport climate goals out of reach

In summary, including transport in the ETS would mean much smaller ZEV production stimulation. This option thus would postpone ZEV mass-market penetration.

A recent and detailed review about the option to include transport in ETS, basically drawing the same conclusions, can be found here: http://www.theicct.org/sites/default/ files/publications/ICCT_EU-ETS-perspective_ 20141204.pdf.

5) Effort Sharing Decision: Brings many uncertainties

Under the Effort Sharing Decision (ESD), Member States have to reduce their greenhouse gas emissions from the sectors not covered by the EU-ETS, such as housing, agriculture, waste, and transport (excluding aviation).

All Member States have taken on national emission targets for 2020, which are expressed as a percentage change from 2005 levels. The ESD only began in 2013, so little experience has been gained on its effectiveness so far.

- Together, the national ESD targets give an overall EU CO_2 reduction of 10% in the non-ETS sectors.
- The ESD also offers flexibility and trading options to comply, including the option to achieve more than half of the reduction efforts by using international offsets.

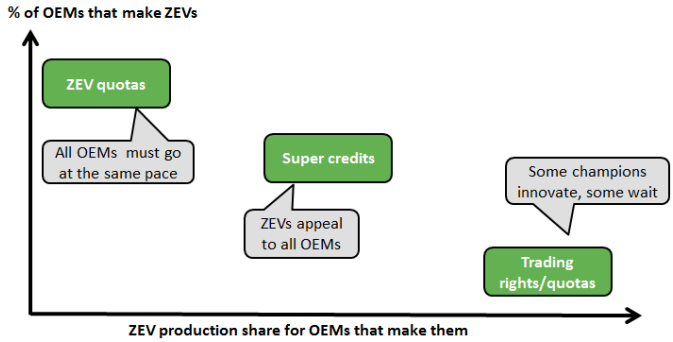
There are three reasons why the ESD as such will not create an incentive for ZEV adoption:

1) The ESD defines overall targets for non-ETS sectors; it does not contain concrete sectoral instrumentation.
2) The possibility to shift reductions from one sector to another (such as in the ETS) means that reductions will not necessarily happen in the transport sector. Rather, they will take place in sectors that have lower abatement costs.
3) Even if the transport sector would contribute to the ESD emission reduction targets, ZEVs are not necessary to reach this. In fact, ICE efficiency improvements would allow to reach the target at a lower cost.

In summary, the ESD will not enhance ZEV mass-market penetration.

Positioning the options to accelerate ZEV sales (ETS and ESD do not have a positive impact)

The analysis of the current and projected EC regulations on CO_2 limits for cars showed that reaching the ambition of 10 g/km in 2035, consistent with a Dutch zero-emission capable passenger car fleet in new sales, would require an ambitious European post-2021 policy.



Roughly speaking, reaching this ambition would require the implementation of the lower target proposed for 2025 of 68 g/km, followed by an annual decrease of the CO_2 limit that linearly follows the same pace over the next decade.

If the EC regulations develop in a less ambitious direction, three additional mechanisms may enhance ZEV market uptake in addition to the impact of the baseline CO_2 regulation:

- ZEV quotas
- Super credits
- Trading of emission rights (in CO_2 emissions and/or quotas).

The picture above summarises some key characteristics of these three options and positions them along a vertical axis of the % of OEMs that will be incentivized by the policy to produce ZEVs, versus on the horizontal axis the impact on the share of ZEV in the production of the OEMs involved. Essentially, a quota system leads to all OEMs producing some ZEVs, while introducing trading options allows for more specialisation among OEMs. Super credits have a position in-between.

Concluding policy recommendations

- Reaching 100% Zero-Emissions Vehicles (ZEVs) sales in NL in 2035 - incentivised by European post-2021 CO_2 policy alone - would require a low 2025 CO_2 emissions target (about 68 g/km), followed by an annual decrease of the CO_2 limit at about the same pace.

- Super credits are an attractive supporting option on the short-term, if bounded by both a low bonus factor and an overall cap.They also need to be phased out with increasing ZEVs share.

- Introducing ZEV quotas could be considered if the European post-2021 CO_2 trajectory will lack ambition and a long-term target. The option of tradable ZEV quotas offers the highest flexibility.

- Including transport in the ETS, as an alternative for the vehicle CO_2 standards, would mean a much smaller stimulation of ZEV production and thus would postpone ZEV mass-market penetration. Likewise, the Effort Sharing Decision on its own will not enhance ZEV mass-market penetration.

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