Towards less cheating and more results in European CO2-emission targets for road transport

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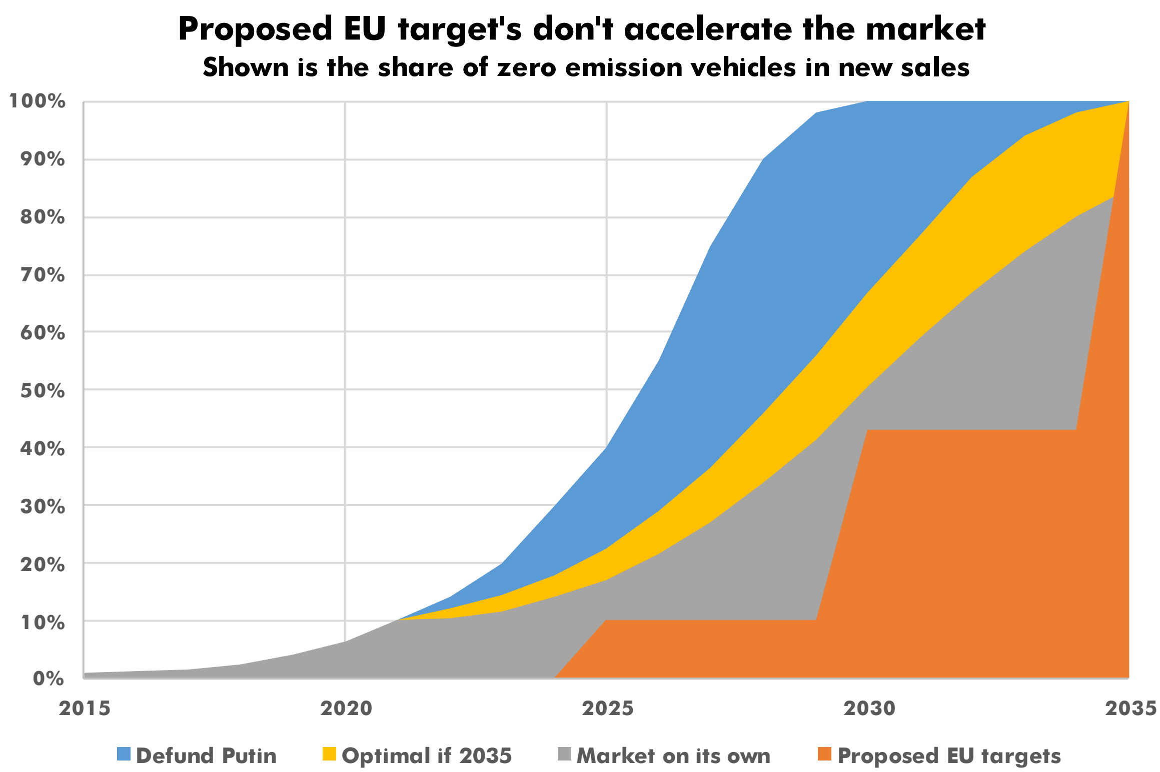
White paper with a plea for yearly targets, correct measurements, targets that don't lag behind the market, and defunding Putin's war



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Management summary

1 Yearly targets make the market improve continuously instead of doing nothing for long periods

Multi year targets are an idea of lobbyists. It means industry only needs to change in target years. Yearly targets avoid gaming the system and stimulate continuous growth.

2 Correct emission measurements: is the EU unwilling or outsmarted?

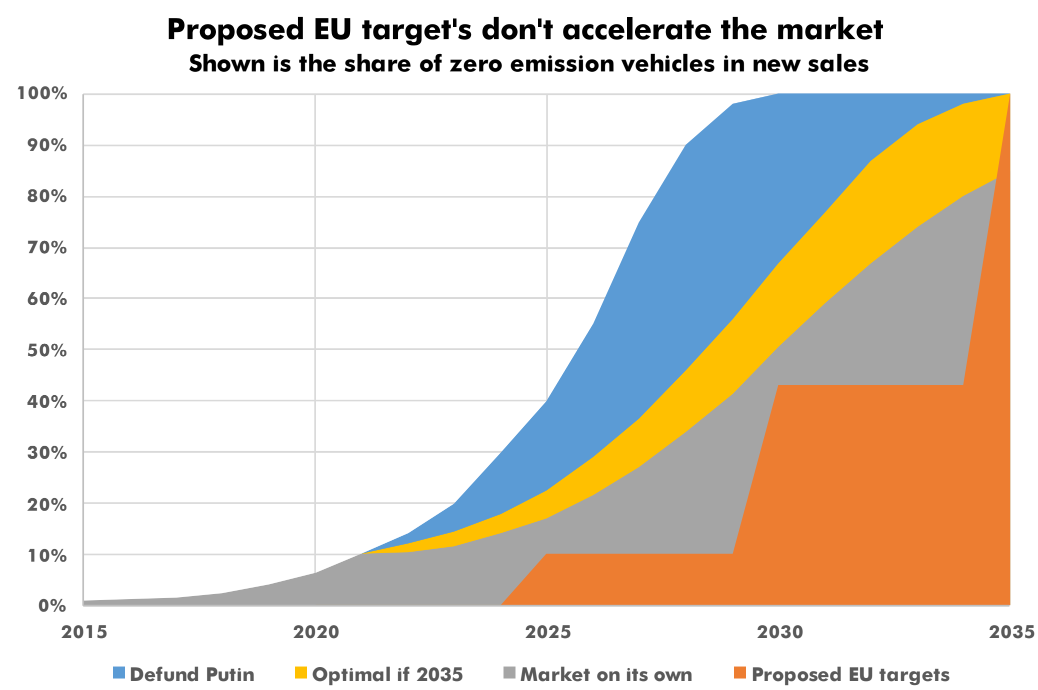
The US shows correct emission measurement is not hard but the EU is unable to implement them. The NEDC was 40% below reality; dieselgate was discovered by the US; and the emission *increase* during 2016-2019 with a decrease in target year 2020 was evidence of cheating.[1] The WLTP is still full of loopholes and plug-in hybrids are emitting 2-4x more CO_2 than assumed. Reality based road tests or independent adversarial tests are needed as soon as possible.

3 Targets that encourage the market: current EU targets lag behind market adoption

Based on trends in cost reduction, battery electric vehicles will be cheaper to buy and much cheaper to own in 2027-2030. EU targets are lagging behind market developments. We evaluate the potential to scale up ZEV demand, ZEV production, scaling up charging infrastructure, battery production, and raw material production. We conclude these are not credible constraints.

4 Defunding Putin's war on Ukraine

We explain the EU could decide to set a target of 100% new ZEV sales by 2030.



About the authors

We are independent academic researchers with a long experience in researching zero emission vehicles. We realise this position paper doesn't present anything new for the ZEV research community but hope this plain spoken document manages to reach a wider audience.

We have not received payment for this position paper and have no conflicts of interest.

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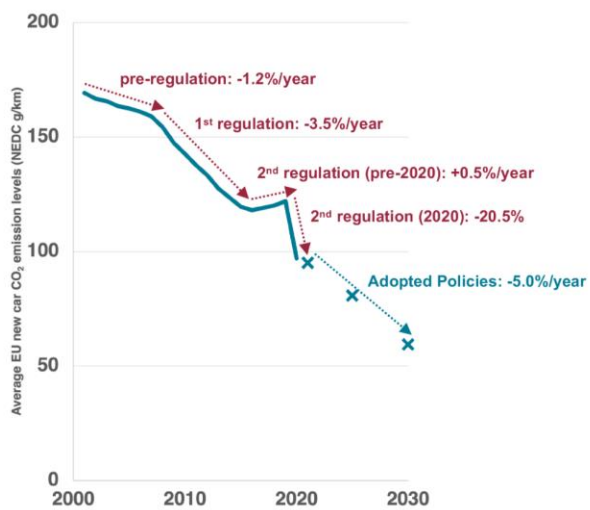
1 Yearly targets to stimulate continuous improvement

Multi-year targets are a goal of lobbyists that want to distort and reduce emission reduction.

Suppose you where the CEO of a car company selling internal combustion vehicles (ICEVs) and zero emission vehicles (ZEVs). Further suppose you had an emission reduction target that you saw as standing in the way of maximizing profits or simply uncomfortable because it forced you to change. Which of the compliant scenarios shown below would you choose?

Year	Reduction target	EU expectation	Target optimized
2021		10%	10%
2022		12%	10%
2023		13%	10%
2024		14%	10%
2025	15%	15%	15%
2026		23%	15%
2027		31%	15%
2028		39%	15%
2029		47%	15%
2030	55%	55%	55%
2031		64%	55%
2032		71%	55%
2033		78%	55%
2034		86%	55%
2035	100%	100%	100%

The picture below shows what happened when there was a clear target in 2020 but not in the years before that. We see an *increase* in the 2016-2019 period and a sudden drop in 2020.[1]



While we understand car maker lobbyists prefer multi-year targets, it's naive to assume this optimally encourages carmakers during the years when the target doesn't increase. So we see it as caving into lobbyists while giving lay persons the impression more is achieved than in reality.

In order to create a healthy regulatory environment for carmakers and reduce cheating and cynicism about EU politics we strongly advice to implement yearly targets.

2 Official emissions in line with real world emissions

Currently the EU encourages cheating until at least 2030 and PHEVs are especially problematic.

Correctly measuring vehicle emissions is not difficult. For example the EPA in the US shows us how it's done. Instead the measurements the EU uses are far below reality. Why is that?

The reason is simple: in the US the measurements are made by an independent watchdog that is rewarded for accuracy, while in Europe the measurements are paid for by the carmakers who try to make their cars perform better in the test than in reality. The European system is an open invitation to cheating and every carmaker is forced to go along to stay in business.

A good example of what the EU could aspire to is the website of the EPA: fueleconomy.gov. Here citizens can compare the energy use of different vehicles based on accurate measurements.

A good example of what the EU has achieved is visible in the chart below. The discrepancy between real world emissions and official NEDC tests increased to 40% in 2016.[2]

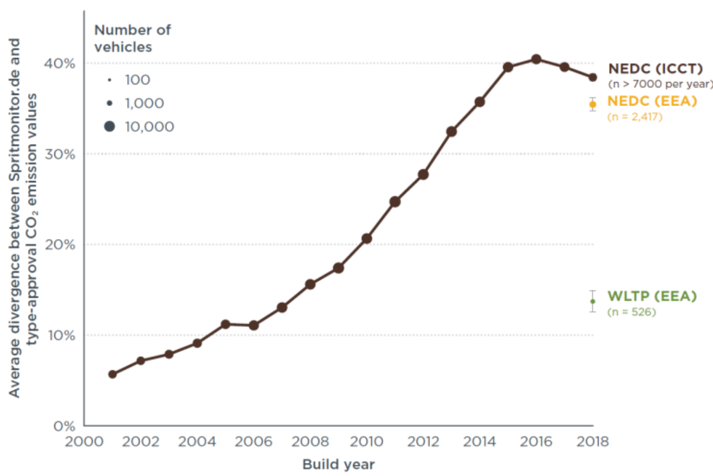


Figure ES-1. Divergence between Spritmonitor.de and type-approval CO_2 emission values over time, including a differentiation of the divergence for those vehicles that were registered in 2018 and were type-approved to the WLTP.

The industry presents WLTP as the solution but it's *already* 14% too optimistic and doesn't address the root problems of independence and enforcement. As Peter Mock, senior manager of the ICCT formulates it: “Improving the test cycle won´t help if we don´t have better enforcement. It is as if a teacher would change the exam questions but then still leaves the room during the exam.”[3]

When an independent watchdog is too much to ask, using the on-board consumption meters that every new car has could solve the problem too. But the implementation is endlessly delayed.

In the understated lingo of the ICCT: "As part of the CO_2 standards regulation, the European Commission is required to assess how data from fuel consumption meters may be used to prevent the real-world gap from growing, by June 2023 at the latest. In 2027, the European Commission must furthermore assess the feasibility of adjusting each manufacturer's average CO_2 emissions to its real-world performance, beginning in 2030. With respect to the tremendous importance of realistic CO_2 emission values for the success of the European Green Deal, this timeline should be expedited."[2] Formulated more bluntly: it's unacceptable that the European Commission wants to wait until 2030 before it might finally end it's encouragement of cheating.

An egregious example that is especially problematic for current CO_2 reduction targets is that Plug-in Hybrid Electric Vehicles (PHEVs) *emit two to four times more CO_2* than in the official tests.[4] We agree with experts that predict PHEVs will become the new dieselgate where the regulatory capture of the EU is again exposed, weakening the trust in the institution.[5]

Not an error but a misunderstanding for some is that the comparison with ZEVs is unfair because ZEFs are not really zero emission. E.g. producing batteries and electricity emits green house gas (GHG). This is correct but we also leave out e.g. fossil fuel production which adds 20-30% GHG. Right now BEVs already emit around a third of GHG and their emissions are becoming less fast.[6]

Here's a list of some of the ways in which the EU provides carmakers with emission loopholes:[7]

- Assuming PHEV's emit 2-4x less than they emit in reality.
- Using carmaker paid WLTP tests (14% more optimistic than reality and probably rising).
- Mass adjustment (if you make your vehicles heavier, you are allowed to emit more GHG).[8] This loophole will probably double to around 5 g/km in 2024.
- Eco-innovation (approved features to emit more GHG) increasing to 3g/km in 2024.
- Pooling (since most carmakers easily meet the targets, laggards can pool with them).
- WLTP uplift (rewarding NECD errors with a transition period to the lesser WLTP errors).
- Super-credits (sell battery electric vehicles so you can emit more GHG in total until 2022).
- 2020 phase-in (exempting the 5% most polluting vehicles in 2020).

In the next chapter we show that these loopholes, together with the adoption of BEVs due to technological innovation will make the currently proposed EU emission reduction goals irrelevant to the market until 2035.

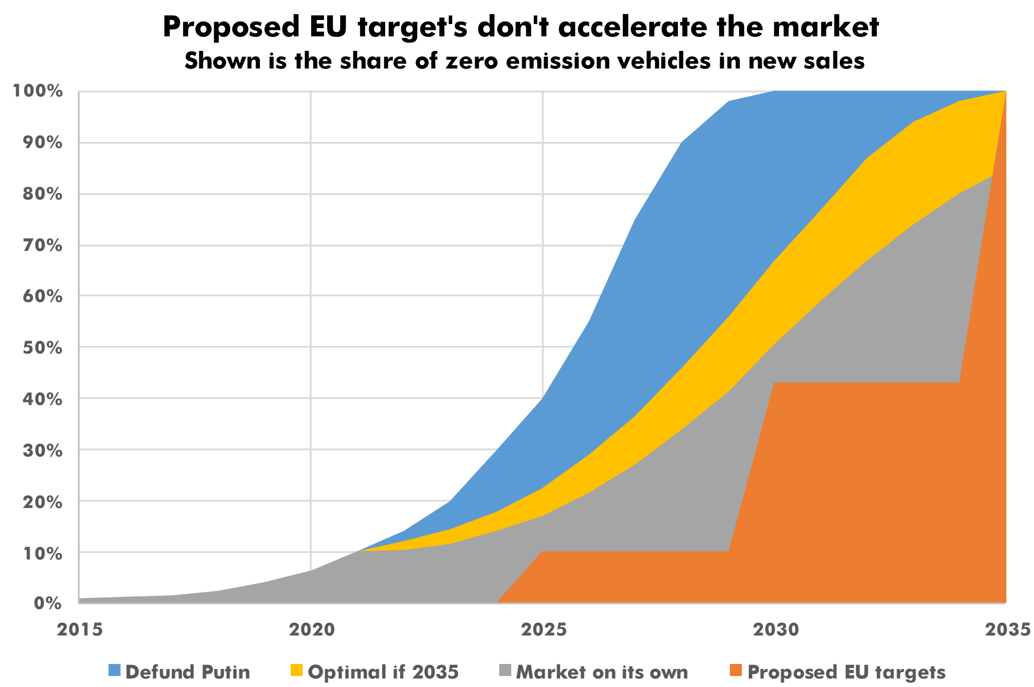
If more ambitious emission goals are chosen, it is important to account for bias inherent in the aforementioned loopholes and to reduce the number of loopholes and to avoid adding new ones. Focusing on ZEV adoption will bypass these loopholes and might be a more prudent strategy.

3 Targets that make the market go faster, not slower

The graphic below (see Annex A) illustrates the problem: the ragged teeth (caused by ill advised multi-year targets) never "bite" the market. The market will develop faster on it's own than proposed EU targets require. Only laggards among carmakers might be somewhat impressed.

Our recommendations:

- Never go below the yearly goals implied by the "Market on it's own scenario".
- If 100% ZEV by 2035 is a serious goal, at least match the "Optimal if 2035" scenario.
- If the EU wants to go 100% ZEV in 2030 it should match the "Defund Putin" scenario.



Expressing this in terms of official EU emission reductions is problematic due to a plethora of loopholes and distortions (see chapter 2). However, our best estimate is shown in the table below.

3.1 Battery electric vehicle demand will facilitate rapid adoption

As described in chapter 2, EU CO2 emissions are riddled with loopholes. We focus on battery electric vehicles (BEVs) because they will become cheaper to buy before 2030 (without subsidies). Furthermore their four times lower energy use and far lower maintenance requirements make them much cheaper to operate.

Cars using hydrogen fuel cells (FCEVs) or eFuels are also welcome ZEVs but we don't expect they will develop a compelling business case before 2035.
If FCEVs or eFuels exceed our expectations this would facilitate even faster ZEV adoption.

Annex B gives more details on BEV adoption (and the alternatives FCEVs and eFuels) but the bottom line is that even in our most ambitious scenarios, customers are unlikely to be the bottleneck for ZEV adoption.

3.2 Charging infrastructure is important but not a credible constraint

Standardizing and implementing charging infrastructure is a valuable and cost-effective contribution the EU can deliver to ZEV adoption. We recommend requiring open standards (like the Open Charge Point Protocol (OCPP) and ISO 15118), stimulating interoperable payment methods (without favouring market leaders like credit card companies), and subsidizing a Europe wide fast charging network (also for eTrucks). Furthermore, seeing the electric vehicle as a 'battery on wheels' and facilitating *smart charging* and even *vehicle to grid* will avoid grid congestion (and thus grid investments) while improving the business case of intermittent energy sources.

However, the experience in e.g. Norway and the Netherlands shows that a lack of centrally mandated charge points does not result in a lack of demand. Furthermore, compared to producing BEVs, rolling out charging infrastructure can be done relatively quick and cheap.

3.3 Scaling up ZEV production is not a credible constraint

If there is enough demand and if there are enough batteries, most experts we talked to considered scaling up BEV production as the least credible constraint. There are already enough car factories. Retooling those to produce different car types is something that carmakers do all the time and from a production perspective, manufacturing a car with a different drive train falls well within possible retooling parameters and battery electric vehicles are simpler to produce. So retooling a factory should be possible within two years.

One could even say that retooling factories in order to produce different car types is something carmakers are increasingly good at. And they are increasingly good at reusing each others' platforms in the process. The Volkswagen MEB (modular electric drive matrix) is an excellent example pertaining BEVs and could be used to quickly scale up BEV production for a range of BEV car models.

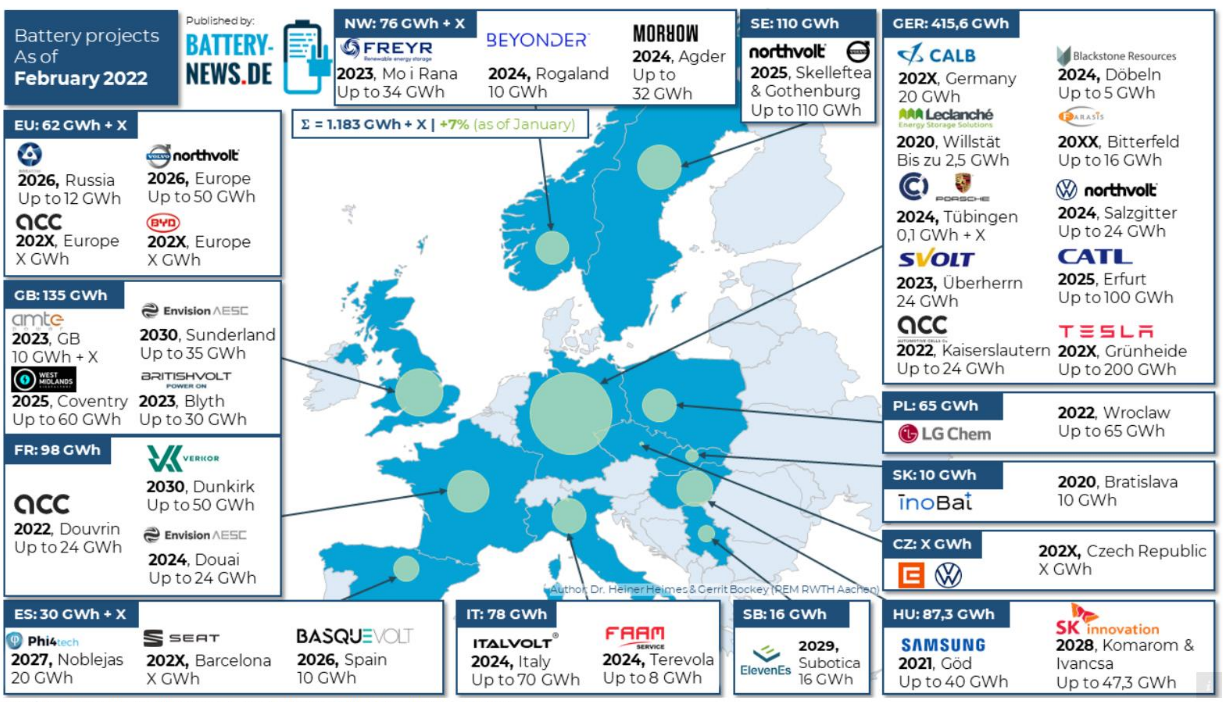
3.4 Battery production is not a credible constraint

Over *one terawatt hour* of car batteries could be produced yearly in 2025 if we accumulated all current plans (see picture).[9] To put this into perspective: we expect batteries for BEVs to be around 60 kWh per vehicle on average in 2025. So that means (very roughly) that *if* these plans materialize, almost 20 million full BEVs would be produced every year already in 2025. That would be around 150% of total expected car sales (not just BEVs) in Europe in 2025.

This is around fifteen times the number of batteries needed to achieve the EUs 2025 CO2 targets and four times more than our most ambitious "Defund Putin" scenario.

On top of that an ambitious EU policy might lead to more cars and batteries delivered to Europe instead of the rest of the world. Obviously the goal is to export ZEVs and not to import them (and the battery production plans seem to indicate this is possible) but the fact that Europe is part of a global market makes it highly unlikely that battery production would be a constraint for ZEV adoption in Europe.

This indicates that in order to support these plans to build battery factories, the EU should adopt much more ambitious goals than it's currently doing.



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3.5 Raw materials for batteries: we have options

So we have seen adoption is unlikely to be a constraint due to BEVs becoming much cheaper to own, long before 2030. We've seen retooling factories to produce BEVs is not a credible constraint and neither is battery production. But what about running out of raw materials to produce these batteries with?

The bad news is that there could be temporary bottlenecks due to unexpected growth. The good news is threefold:

1. These bottlenecks are temporary because we have enough raw materials in the long term.
2. There are many options for substitution if a few specific raw materials are the bottleneck.
3. The EU could play a starring role in preventing continuing boom-bust cycles.

Material scarcities most talked about are cobalt, nickel, and lithium. Most of the problem can be attributed to temporary supply squeezes from a conservative industry surprised by the popularity of electric vehicles.

For example: in past decades many lithium mines closed as uneconomical and lithium was mostly produced in South American salt flats. But producers where not prepared for the increased demand. So most lithium now comes from rock mining in the deserts of Australia where producers where able to scale up quickly. And new concepts like lithium from geothermal brine and from sea water are quickly gaining interest and some closed mines are now considering reopening. Long term we have already allocated enough lithium to replace all current cars worldwide with BEVs using lithium batteries and that's just a fraction of the lithium in the upper earths crust. Mining lithium from seawater would increase the available amount of lithium with a factor of five thousand.

More importantly most people forget that batteries are a field that is developing rapidly[1] and that there are literally *dozens* of chemistries moving from the laboratory to factories. If cobalt or nickel or lithium become scarce we have options. Cobalt is on its way out in almost all chemistries. Nickel can be replaced by e.g. iron (LFP) or sulphur (Li-S). Solid state electrolytes, lithium-metal anodes, and the application of graphene in batteries all offer enticing glimpses into the many revolutions that await us regarding batteries. Even lithium could be replaced. E.g. by sodium (which is of course even more abundant than lithium) and is heavily promoted by the worlds largest battery manufacturer CATL.

[1] An interesting statistic is that more battery literature has been published in the last five years than before that.

4 Defund Putin: decreasing EU dependence on oil

We think the CEO of BMW was mistaken when he claimed - after the invasion of Ukraine - that the EU should delay it's plans to phase out combustion engines because that could make us dependent on raw materials for batteries.

To us it seems clear that it is the other way around: our dependence on Russian fossil fuels gives us a reason to *accelerate* the phase out of the combustion engine.

By now everybody knows that we are funding Putin's war on Ukraine with billions per week because we are buying Russian oil, gas, coal. Oil represents the biggest donation in terms of money. In the decades before this we had multiple oil crises and terror attacks that drove the message home that our dependence on oil is causing us to fund undemocratic regimes with values at odds with those of the EU. Putin's war underscores that it's time to quickly phase out our reliance on oil. It's no longer just a calculation based on the cost of CO2 emissions. We should also take the costs of war and the wealth redistribution from democratic to undemocratic governments into account.

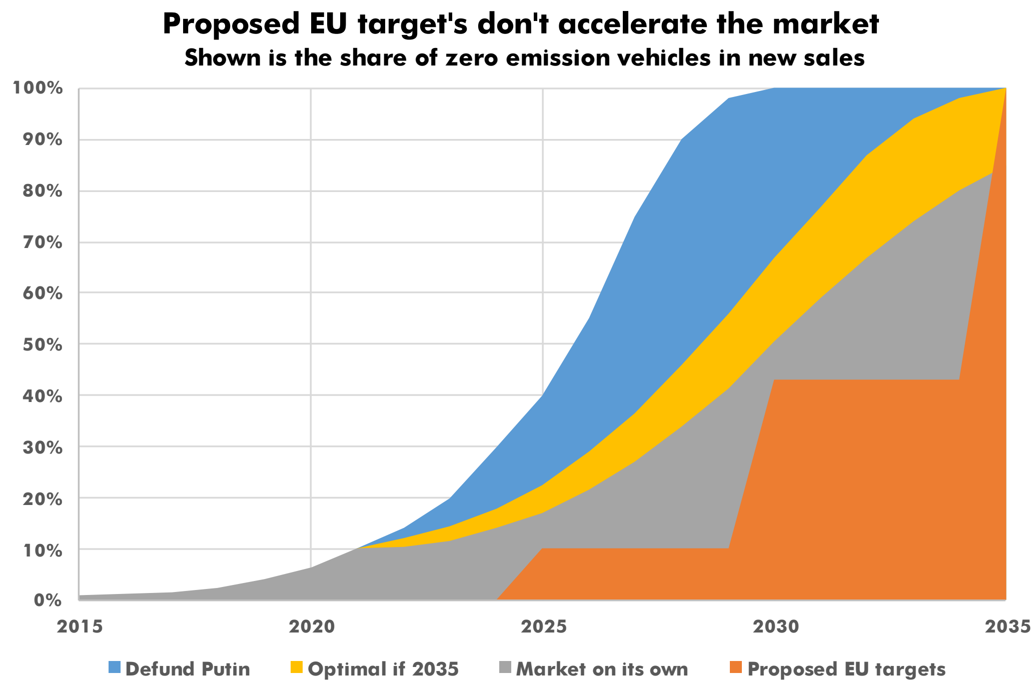
Our dependence on battery materials is fundamentally different for at least four reasons:

1. If fossil fuel flows stop, the problem is almost immediate: you get cold this winter and your car stops driving when the tank is empty. Instead, solar panels and electric vehicles will keep working for decades so there is much less room for blackmail.
2. Fossil fuel flows are much bigger in terms of money, volume, and weight. Take the Ford F150, a large pickup truck that is the bestselling car in the US. It needs around 300 barrels (40 tonnes) of oil over its lifetime. With current oil prices we have to pay Russia around 30 thousand Euro's for that. On the other hand the raw battery cell materials for the electric 130 kWh version weights 500 kilo's and cost less than one thousand euros.
3. Fossil fuel is burned while battery materials are recycled. With current technology we can already recycle over 95% of the battery. So for the Ford F150 battery we would only need to import 25 kilo costing 50 euros per giant car. Admittedly we don't recycle electric car batteries at scale yet but that is mainly because there are almost no electric cars ready to be scrapped yet.
4. Substitution of fossil fuel is harder for two reasons. First fossil fuel is used by the finished product so switching from a fossil fuelled car to something different usually means building a new car which is very costly. With raw materials you replace at the start of the production process. E.g. by producing a different battery which is not very costly. Second the amount of raw energy you need is hard to replace: eFuels are an example where you need five times the number of windmills compared to an electric vehicle. With battery materials you could simply replace nickel-cobalt-aluminium lithium batteries with iron-phosphate lithium batteries with limited implications for the supply chain.

All in all, if we start thinking out of the box just a little bit, and if we account for the wider costs and the geopolitical and humanitarian implications of our actions, choosing a scenario where we sell 100% ZEVs in 2030 in Europe becomes entirely plausible in our opinion.

Annex A: ZEV adoption curves explained

We give a brief explanation on how we constructed this graph.



Here are the numbers in a table for easy reference:

Year	Proposed EU target	Market on its own	Optimal if 2035	Defund Putin
2023	0%	12%	15%	20%
2024	0%	14%	18%	30%
2025	10%	17%	23%	40%
2026	10%	22%	29%	55%
2027	10%	27%	37%	75%
2028	10%	34%	46%	90%
2029	10%	42%	56%	98%
2030	43%	51%	67%	100%
2031	43%	59%	77%	100%
2032	43%	67%	87%	100%
2033	43%	74%	94%	100%
2034	43%	80%	98%	100%
2035	100%	85%	100%	100%

We use ZEV sales as the metric instead of CO2 reduction because of the many flaws in CO2 calculations in the EU. Right now the 100% ZEV by 2035 goal is the clearest and strongest goal.

We approximate ZEV with BEV because right now they are the only ZEVs sold in quantity and alternatives like eFuels and hydrogen vehicles get a lot of press but fail to show a business case.

The "Market on its own" scenario is based on the Bloomberg New Energy Finance (BNEF) report[10] that predicts adoption based on price developments in the production of electric vehicles. BNEF has a large team with a refined methodology and has (as far as we know) the best track record for making these predictions over the past ten years. But in simple terms it comes down to this: 1) Because electric drive trains and batteries become cheaper, electric vehicles will become cheaper to buy than combustion engine alternatives between 2027-2030 in all segments in Europe. 2) On top of that they require four times less energy and less maintenance which makes them *much* cheaper to own. 3) That's why most people will start buying them eventually.
We also estimate that pledges by car makers are as least as ambitious as this scenario.

For the impact of proposed EU targets on actual ZEV adoption needed to be compliant we used the estimates of Transport and Environment that made the most detailed and explicit report on how different loopholes regarding CO2 emissions stack up to make targets less stringent for car makers.[7]

Annex B Battery Electric Vehicle Adoption

While the emissions per km of combustion vehicles are not materially decreasing, the EU is seeing a remarkable reduction in emissions per km, driven by plug-in hybrid electric vehicles (PHEVs) and fully battery electric vehicles (BEVs).[2] Fuel-cell electric vehicles (FCEVs) running on hydrogen have long been predicted by industry to also play a role - and there is nothing wrong with targets being technology neutral where that doesn't hurt their effectiveness - but so far almost no FCEVs are produced and sold and even companies that used to tout FCEVs (like Toyota) are increasingly aiming for PHEVs and BEVs.

Especially BEVs are quickly getting cheaper and will not need government support forever. Their biggest advantage is that they need around four times less energy because their motor wastes less than 5% of energy in the form of heat, while combustion engines on average waste 75% of their energy as heat.[3] Since electricity and gasoline are priced and taxed roughly evenly (although with big swings per market segment and member state) needing four times less energy means much lower energy costs for electric vehicles. Maintenance costs are also much lower (since the drivetrain doesn't need servicing). For that reason the total cost of ownership is already lower without subsidy in many use cases where the amount of kilometres driven is high.

The sticker price of BEVs is still higher and this currently impedes rapid adoption without government intervention. The reason is the high costs of batteries but here there is a clear downward trend. E.g. battery prices have dropped a stunning 98% since 1991: a 40 kWh Nissan Leaf battery costs manufacturers around $5.500 in 2021 but would have cost $300.000 in 1991.[4] These developments will continue. Bloomberg New Energy Finance (BloombergNEF) makes some of the most detailed cost breakdowns and they expect electric vehicles to become cheaper in the showroom (without subsidy) between 2025 to 2027 (depending on segment). So in 2027 BEVs will not only be cheaper to drive but will also have a lower sticker price and there will be no financial argument anymore that leads to including a combustion engine in cars. Basically BEVs are poised to take over the car market from combustion engines in a way that is analogous to the way LED lighting took over from incandescent light bulbs. Since BEVs have lower emissions the EU should accelerate this transition.

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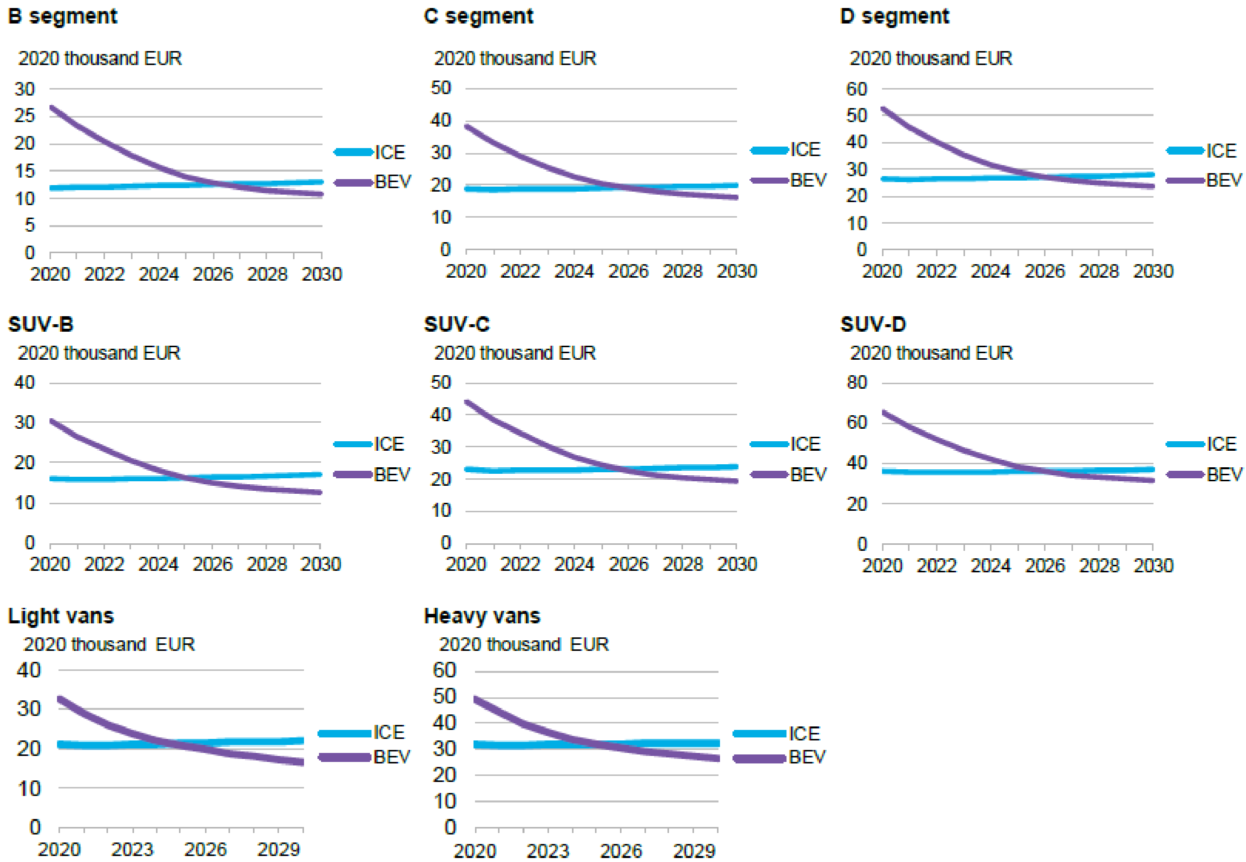
[2] E.g. see the graph on page 23 of the ICCT working paper.[11]

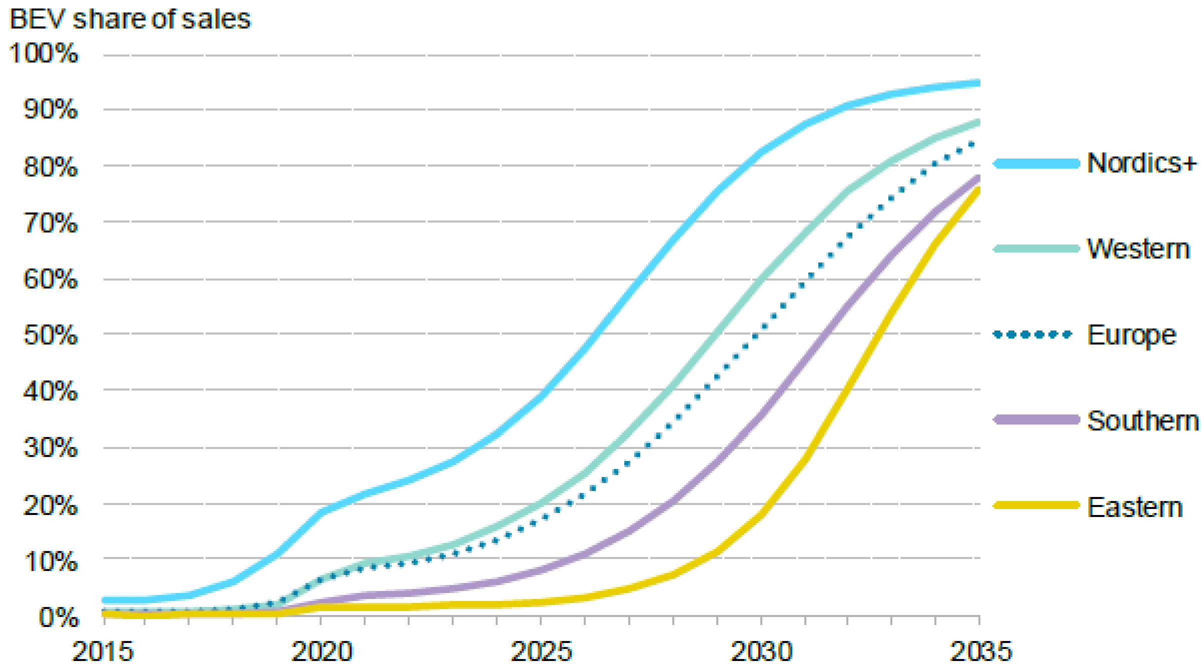
[3] Combustion efficiency can be as high as 50% in the laboratory but on in production vehicles the maximum efficiency is closer to 35% and this is only achieved during very specific loads and RPMs. In real life use one has to account for all driving conditions and on average around 25% is realistic. This has hardly changed in the past three decades.

[4] Using the 1991-2018 period, Our World In Data charted a 97% price reduction. Using an update for 2020 from Bloomberg New Energy Finance brings it down to $137/kWh or 98%.

The following graphs show the expectations of BloombergNEF regarding pre-tax retail prices.[10]



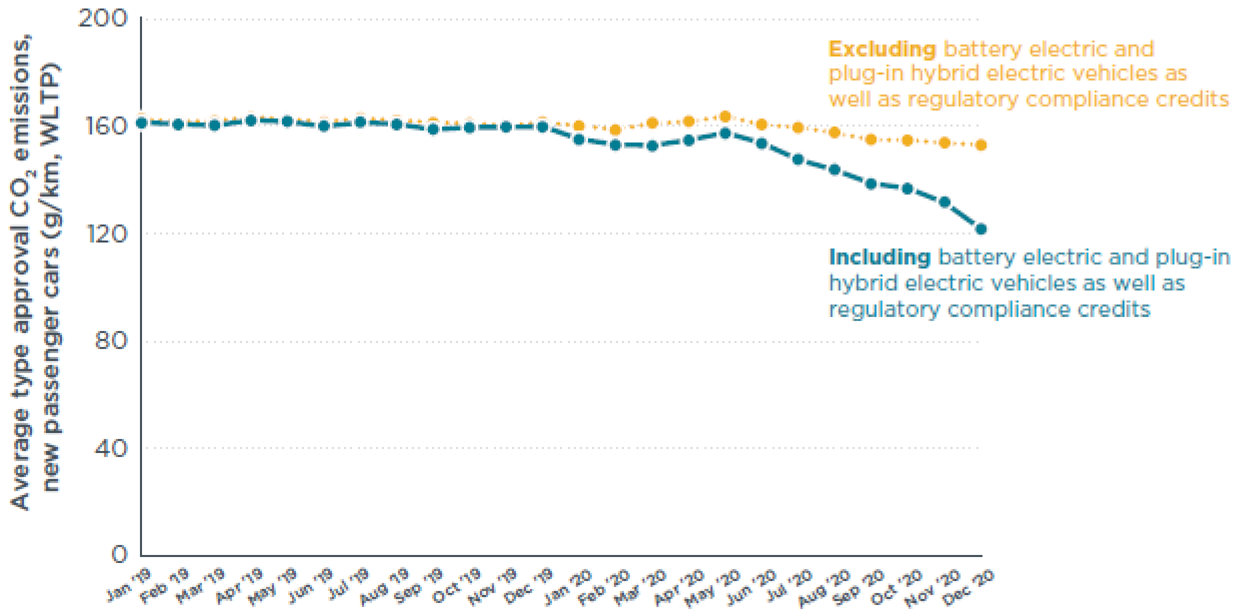
And here's their expectation regarding adoption based on that. In the figure at the start of this document we used the average adoption curve for Europe.



Source: BloombergNEF. Note: The Europe adoption curve shows the adoption for all four regions combined according to their sales. Includes adoption of battery electric vehicles (BEV) only; does not include plug-in hybrids (PHEV). Base case shows trajectory under current economic development and policy measures, but does not take into account any constraints due to charging infrastructure, raw material availability or other factors.

ICE is hardly improving

If we look at recent reductions in the CO2 emissions of ICE power trains we see they are almost stagnant and would at best contribute a small percentage of required production if emissions where to continue along it's current trajectory. (See picture from the ICCT, page 23[11], below. Note that this includes WLTP errors and ignores both electricity production and fuel production.)

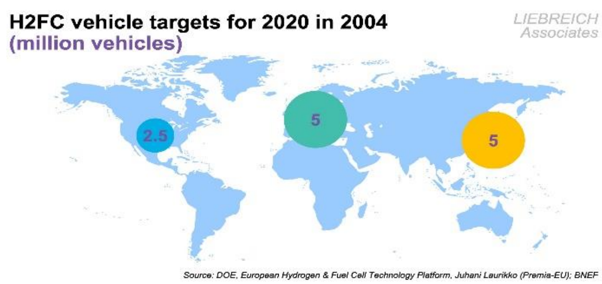


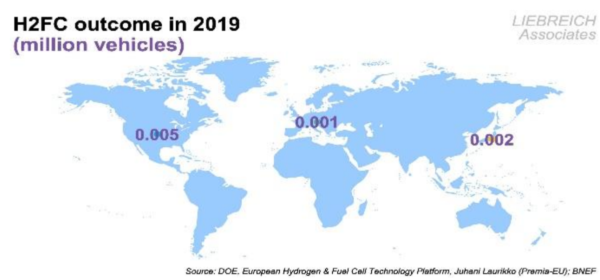
PHEVs have limited impact

As discussed under the paragraph on realistic measurements, PHEV CO2 emission reductions are two to four times lower than official tests indicate. We hope that in time this measurement error will be corrected, if only through less subsidies. It also indicates that the real world energy reduction in PHEVs is limited compared to BEVs. This means the reduction in running costs will also be limited while the double drivetrain increases production and maintenance costs compared to BEVs. Over the last five years we see an increasing consensus that PHEVs have limited added value with regard to BEVs as battery prices come down.

FCEVs are a promise that still has to pan out

People sometimes joke that nuclear fusion is always 30 years in the future. With FCEVs the time frame is shorter but the prediction of growth is both consistent and absent. Liebreich and associates made a comparison of FCEV predictions versus reality that underscores this point. (See picture below[5].)



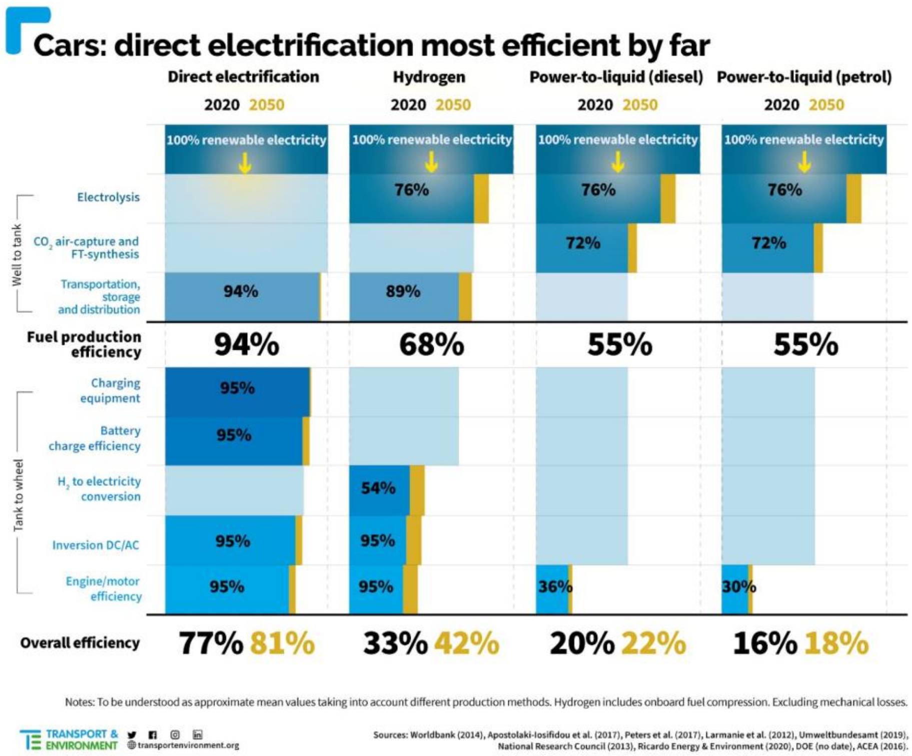


Now it is clear that both green hydrogen and fuel cells could become much cheaper. If green hydrogen and fuel cells indeed become cheaper, and if renewable electricity also becomes so cheap that it doesn't matter anymore that you need twice the amount of energy and if you can combine this with long distance pipelines to territories where solar and/or wind are cheap, this offers interesting opportunities. However, that's a lot of if's. Of course it would be great if FCEVs finally see a breakthrough and that would mean that the yearly goals of the European Union would need to be strengthened.

[5] This is from email correspondence of the author with Michael Liebreich who uses this in presentations.

eFuels in road transportation is mainly a political idea

It seems that especially in Germany, eFuels for combustion engine cars are popular with part of the population. And it has clear advantages: you can use it in existing engines and like oil it's relatively easy to transport. However, the creation is relatively inefficient (see picture below[6]).



Now of course efficiency is not everything but eFuel production is also expected to be more costly than the production of e.g. hydrogen because it requires extra steps. For that reason we find it hard to see how it could get a practical business case in road transport before 2035. Where it might be useful is for all fossile driven cars which are still in the fleet, and in situations in which alternatives are especially hard. For example long distance flying and shipping where batteries might be too heavy and hydrogen might be too bulky.

[6] This visualization was made by Transport & Environment in a brief[12] based on a report by Ricardo[13] and we would like to add that efficiencies of 36% for diesel and 30% for petrol are normal in laboratory tests but seldom seen in real life usage which flatters the efficiency of eFuels in this comparison.

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